

APPENDIX I
BIOLOGICAL RESOURCES
PROVIDENCE RIVER AND HARBOR
MAINTENANCE DREDGING



FINAL ENVIRONMENTAL
IMPACT STATEMENT



U.S. ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT

Appendix I-1

**RHODE ISLAND SOUND LOBSTER SURVEY FOR THE
PROVIDENCE RIVER AND HARBOR MAINTENANCE DREDGING PROJECT
FINAL ENVIRONMENTAL IMPACT STATEMENT**

Submitted to

**Department of the Army
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1.0 Introduction

The New England District (NED) of the U.S. Army Corps of Engineers (USACE) is preparing a Final Environmental Impact Statement (EIS) for the proposed maintenance dredging of the Providence River channel and harbor. As part of the Draft EIS, the lobster habitat and resources in the vicinity of the potential dredged material disposal sites were evaluated (see Appendix C-7). The original lobster survey evaluated lobster resources at three sites in Narragansett Bay in November 1996 and at four sites in Rhode Island Sound in August 1997. The lobster habitat at these sites was also evaluated.

Currently, only three of the sites in Rhode Island Sound originally surveyed are under consideration for disposal of dredged material. The three sites, 18, 69a and 69b, are the focus of the lobster surveys summarized in this appendix. Because the habitat at these locations was previously characterized in the Draft EIS and appendices, it is not presented in this appendix.

2.0 Methods and Materials

To help evaluate the three sites for potential suitability as dredged material disposal sites, the lobster study was carried out to determine whether there was a significant difference in lobster abundance between sites 18, 69a, and 69b. Lobster abundance was estimated by setting 20 commercial lobster traps at each site for a specific time period (3 days), pulling the traps, and recording the number of lobsters collected in each trap.

2.1 Sample Size

The study was designed to allow statistical methods, specifically analysis of variance (ANOVA), to analyze the results. The number of traps that needed to be set at each site could be determined with the results of the previous sampling so that a sufficient sample size was obtained to conduct the ANOVA. Assuming a statistical power of 80 percent and a significance level of 0.05, the "effect size" or the number of samples necessary to detect differences among the means could be calculated. Using the 1996 and 1997 lobster data from the Rhode Island Sound and Narragansett Bay areas (USACE NED 1998), the number of samples necessary to detect mean differences in abundance between the sites was calculated. A sample size of 3 traps at each site was determined to be adequate to detect differences in juvenile lobsters, and a sample size of 14 traps at each site was sufficient to detect differences in non-juvenile animals. Because traps are often lost after being deployed, thus rendering them unavailable for collection, 1 additional juvenile trap (4 total) and 2 additional non-juvenile traps (16 total) were added to the calculated sample sizes to ensure that the sample size was sufficient to conduct the statistical analysis.

2.2 Trap Deployment and Collection

Twenty 12-inch x 18-inch x 36-inch lobster traps (4 juvenile and 16 non-juvenile) were randomly deployed at each site and allowed to fish (i.e., soaked) for 3 days. The traps were baited and the escape vents closed to prevent escape by smaller juveniles. Of the 20 total traps, 4 were randomly selected to be juvenile traps and were further modified by covering the trap with ½-inch polyethylene marine netting to prevent escape by small juveniles. Traps were deployed and collected at each site in August, September, and November 1999. Tables 1 through 3 present the latitude/longitude coordinates and the cover status of traps placed within each site for the August 23-26, September 26-October 1, and November 18-21, 1999 sampling events, respectively. Figures 1a through 1c graphically depict lobster trap locations at Site 18 during the August (a), September (b), and November (c) sampling events. Figures 2a through 2c show trap locations for the three sampling events at Site 69a, and Figures 3a through 3c show trap locations for the three sampling events at Site 69b.

Following the three-day set period, all traps were pulled and individual animals were processed by measuring carapace length (CL; to the nearest 0.1 mm), and determining sex and reproductive condition. Observations on any shell pathology and indications of cannibalism were also recorded. All individuals were returned to the environment after processing. Crabs collected in the traps were identified to species, counted, and returned to the environment.

2.3 Statistical Analysis

The number of individuals collected in each trap at each site was used to compare lobster abundance, size (including legal status), sex ratio, and fecundity. Lobster abundance was measured at each site by calculating Catch Per Unit Effort (CPUE), which is defined as the number of lobsters collected in each trap (effort was equal for all traps). CPUE for each site was calculated by pooling the data across all sampling months and comparing site means using a single factor ANOVA. Individual comparisons between any two sites were made using a two-sample t-test. CPUE was also evaluated for each month by pooling the data from all sites and comparing monthly means using a single factor ANOVA. Again, a two-sample t-test procedure was used to compare monthly CPUE means for any two sampling months. Differences in the number of lobsters collected by covered and uncovered traps were evaluated using a two-sample t-test.

Lobster size, as measured by CL (in millimeters), was also evaluated by site (pooling data across all sampling months) and by month (pooling data across all sites). Mean lobster size at individual sites and mean lobster size for each sampling month were compared using single-factor ANOVAs. In both cases, the ANOVA procedure was followed by individual comparisons between any two sites (or months) using two-sample t-tests. Differences in the size of lobsters collected by covered and uncovered traps were evaluated using a simple two-sample t-test.

The total number of lobsters and CPUE of legal and sublegal-size lobsters was also calculated. The total number of females and males, and the CPUE of females and males were calculated. The fraction of the female population that contained eggs was also calculated. Latitude and longitude coordinates for lobster traps set at Sites 18, 69a, and 69b during the August 1999 sampling event.

Table 1. Latitude and longitude coordinates for lobster traps set at Sites 18, 69a, and 69b during the August 1999 sampling event.

Site 18	Trap Number	Longitude	Latitude	Covered? (Y/N)	Site 69a	Longitude	Latitude	Covered? (Y/N)	Site 69b	Longitude	Latitude	Covered? (Y/N)
	1	-71.30498	41.28974	N		-71.32366	41.25032	N		-71.37248	41.24634	N
	2	-71.30498	41.28907	N		-71.33321	41.24919	N		-71.37665	41.24567	N
	3	-71.30946	41.28884	N		-71.33112	41.24897	N		-71.37725	41.24432	N
	4	-71.29842	41.28794	N		-71.32007	41.24762	N		-71.38262	41.24364	Y
	5	-71.30200	41.28772	N		-71.32156	41.24717	N		-71.38232	41.24116	N
	6	-71.30110	41.28772	N		-71.32007	41.24626	N		-71.38142	41.24094	N
	7	-71.30140	41.28749	N		-71.32067	41.24559	N		-71.39067	41.24026	N
	8	-71.29304	41.28749	N		-71.32216	41.24536	N		-71.37606	41.23801	N
	9	-71.31095	41.28682	N		-71.32634	41.24424	N		-71.39126	41.23711	N
	10	-71.30289	41.28479	N		-71.31888	41.24401	N		-71.38619	41.23599	N
	11	-71.30737	41.28367	N		-71.32366	41.24379	N		-71.36979	41.23599	N
	12	-71.30021	41.28322	N		-71.32127	41.24356	N		-71.38083	41.23216	N
	13	-71.30946	41.28209	N		-71.32097	41.24333	Y		-71.37755	41.23149	N
	14	-71.30737	41.28209	Y		-71.31798	41.24311	Y		-71.38500	41.23104	N
	15	-71.30050	41.28097	Y		-71.32306	41.24288	N		-71.38769	41.22721	Y
	16	-71.30080	41.28051	Y		-71.32515	41.24221	N		-71.38023	41.22676	Y
	17	-71.30528	41.28029	N		-71.31828	41.24131	N		-71.37934	41.22653	N
	18	-71.30259	41.28029	N		-71.32097	41.24063	Y		-71.38888	41.22563	Y
	19	-71.30737	41.27939	Y		-71.32276	41.24018	Y		-71.38709	41.22563	N
	20	-71.30558	41.27871	N		-71.32664	41.23950	N		-71.39753	41.22406	N

Table 1 Latitude and longitude coordinates for lobster traps set at Sites 18, 69a, and 69b during the September 1999 sampling event.

Site 18	Trap Number	Longitude	Latitude	Covered? (Y/N)	Site 69a	Longitude	Latitude	Covered? (Y/N)	Site 69b	Longitude	Latitude	Covered? (Y/N)
	1	-71.29692	41.29245	N		-71.3219	41.25145	N		-71.3873	41.24338	N
	2	-71.29185	41.29222	Y		-71.3228	41.25032	Y		-71.3844	41.24046	N
	3	-71.29961	41.2911	Y		-71.3284	41.24987	Y		-71.3972	41.2382	N
	4	-71.29692	41.29065	N		-71.3216	41.24942	N		-71.3871	41.2382	N
	5	-71.30946	41.2902	N		-71.329	41.24897	N		-71.3978	41.23775	N
	6	-71.30468	41.28547	N		-71.3258	41.24897	N		-71.3802	41.23753	Y
	7	-71.30200	41.28457	N		-71.3213	41.24807	N		-71.3799	41.2373	N
	8	-71.29722	41.28299	Y		-71.3171	41.24807	N		-71.3927	41.23595	Y
	9	-71.30021	41.28277	N		-71.3186	41.24739	N		-71.3924	41.23595	Y
	10	-71.29871	41.28164	N		-71.318	41.24604	N		-71.3909	41.23595	N
	11	-71.29633	41.28164	N		-71.332	41.24311	N		-71.3945	41.23438	N
	12	-71.30707	41.28097	N		-71.3183	41.24311	N		-71.3984	41.23325	N
	13	-71.30528	41.28029	N		-71.3234	41.24221	Y		-71.3757	41.23325	N
	14	-71.30737	41.27826	N		-71.3225	41.23995	N		-71.3805	41.23303	N
	15	-71.29573	41.28367	N		-71.3237	41.2395	N		-71.3754	41.2319	N
	16	-71.29364	41.28232	N		-71.332	41.251	N		-71.3903	41.23168	N
	17	-71.29215	41.28142	Y		-71.3192	41.25077	N		-71.3787	41.23123	N
	18	-71.29483	41.28119	N		-71.3311	41.24108	N		-71.3921	41.23078	Y
	19	-71.29155	41.27759	N		-71.3311	41.2395	Y		-71.385	41.22965	N
	20	-71.29245	41.27691	N		-71.3281	41.2395	N		-71.3862	41.22875	N

Table 2. Latitude and longitude coordinates for lobster traps set at Sites 18, 69a, and 69b during the November 1999 sampling event.

Site 18	Trap Number	Longitude	Latitude	Covered? (Y/N)	Site 69a	Longitude	Latitude	Covered? (Y/N)	Site 69b	Longitude	Latitude	Covered? (Y/N)
	1	-71.30164	41.29309	Y		-71.32236	41.25525	N		-71.3841	41.23978	N
	2	-71.29119	41.29264	Y		-71.32983	41.25458	N		-71.3894	41.23888	N
	3	-71.29060	41.29196	Y		-71.32744	41.25435	N		-71.3924	41.23438	Y
	4	-71.30612	41.29151	N		-71.32445	41.25097	N		-71.3906	41.23348	Y
	5	-71.29179	41.29038	N		-71.33640	41.25030	N		-71.376	41.23303	N
	6	-71.29865	41.29016	N		-71.32326	41.24804	N		-71.3745	41.23123	Y
	7	-71.29627	41.28836	N		-71.32535	41.24759	Y		-71.3984	41.23078	N
	8	-71.30701	41.28633	N		-71.31997	41.24759	N		-71.3796	41.23033	N
	9	-71.28910	41.28611	N		-71.31848	41.24759	N		-71.3766	41.2301	N
	10	-71.29657	41.28363	N		-71.32356	41.24669	N		-71.39	41.2292	N
	11	-71.31089	41.28296	N		-71.32475	41.24624	N		-71.3838	41.22898	N
	12	-71.30612	41.28206	N		-71.33042	41.24489	Y		-71.3787	41.22875	N
	13	-71.28910	41.28183	N		-71.33013	41.24399	Y		-71.396	41.2283	N
	14	-71.30791	41.28161	N		-71.31639	41.24354	Y		-71.3924	41.22785	N
	15	-71.30194	41.28048	Y		-71.33311	41.24308	N		-71.3787	41.22762	N
	16	-71.29119	41.28025	N		-71.33072	41.24173	N		-71.3793	41.2274	N
	17	-71.30731	41.27958	N		-71.31729	41.24106	N		-71.3921	41.2265	N
	18	-71.31029	41.27935	N		-71.33610	41.24061	N		-71.3879	41.22582	N
	19	-71.30134	41.27845	N		-71.32147	41.23970	N		-71.3871	41.2256	Y
	20	-71.31089	41.27823	N		-71.33102	41.23925	N		-71.3876	41.22222	N

Figure 1(a). Lobster trap placement at Site 18 during the August 1999 sampling event.

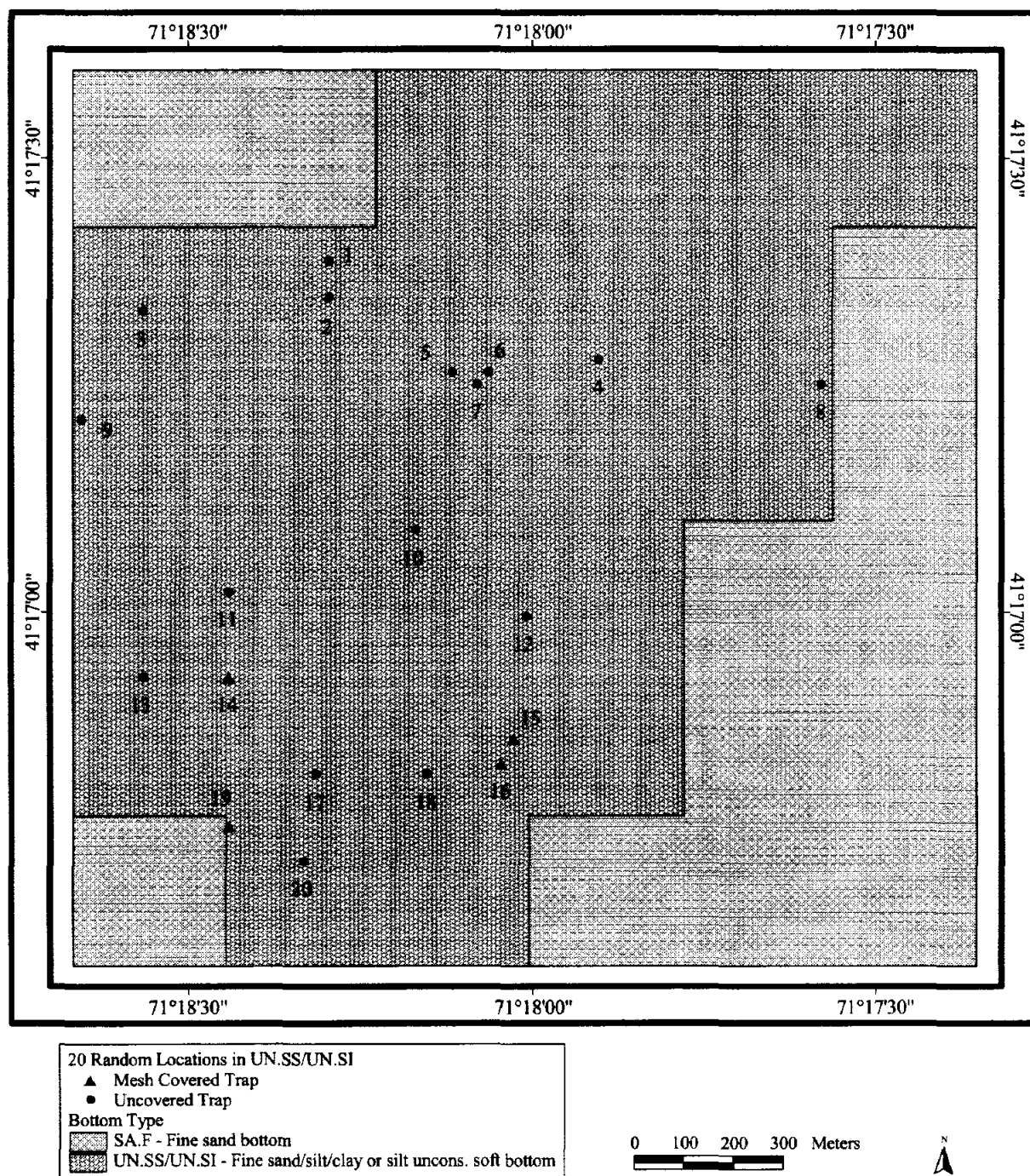


Figure 1(b). Lobster trap placement at Site 18 during the September 1999 sampling event

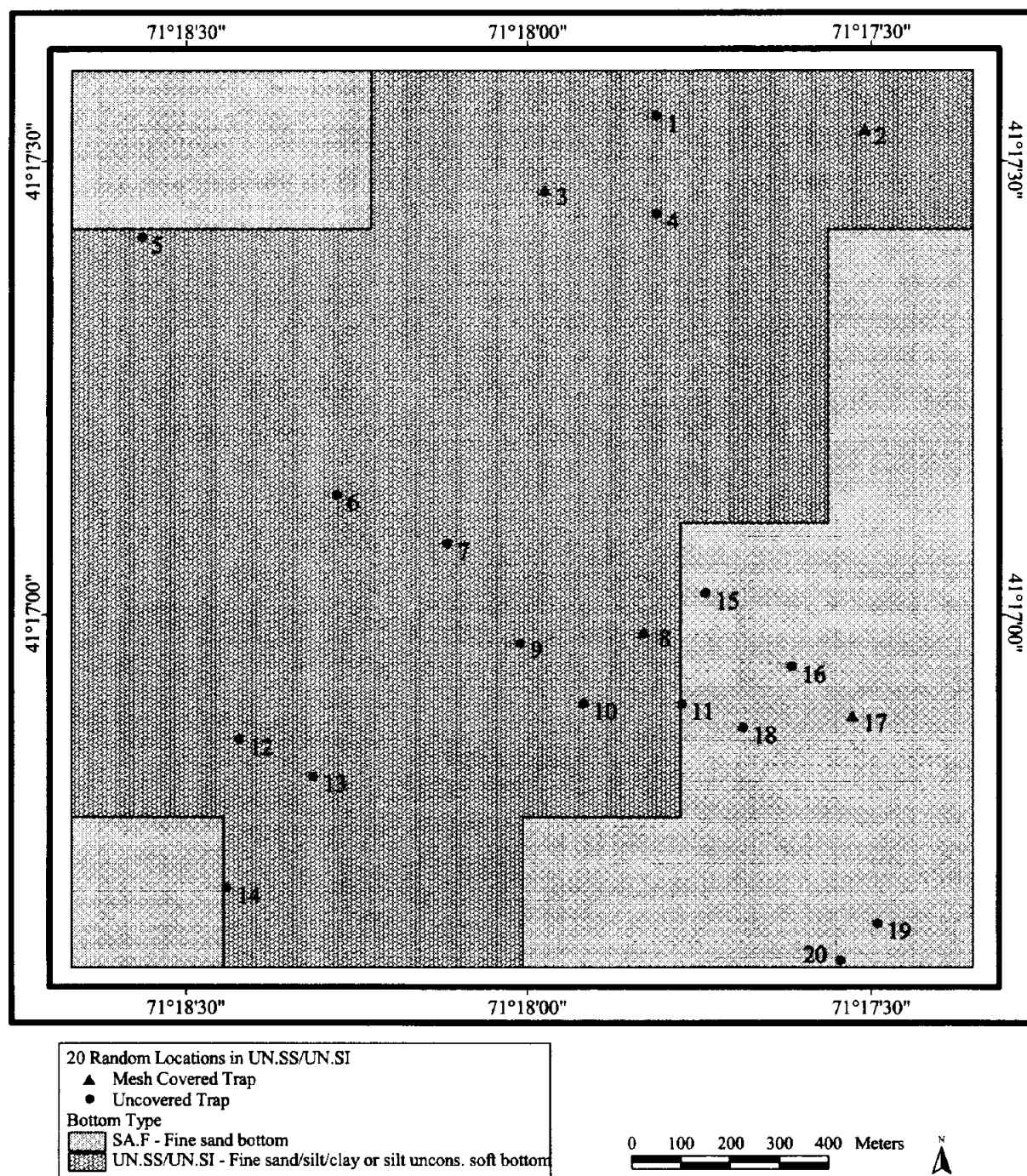


Figure 1(c). Lobster trap placement at Site 18 during the November 1999 sampling event. Two traps were located slightly east of the original site boundary

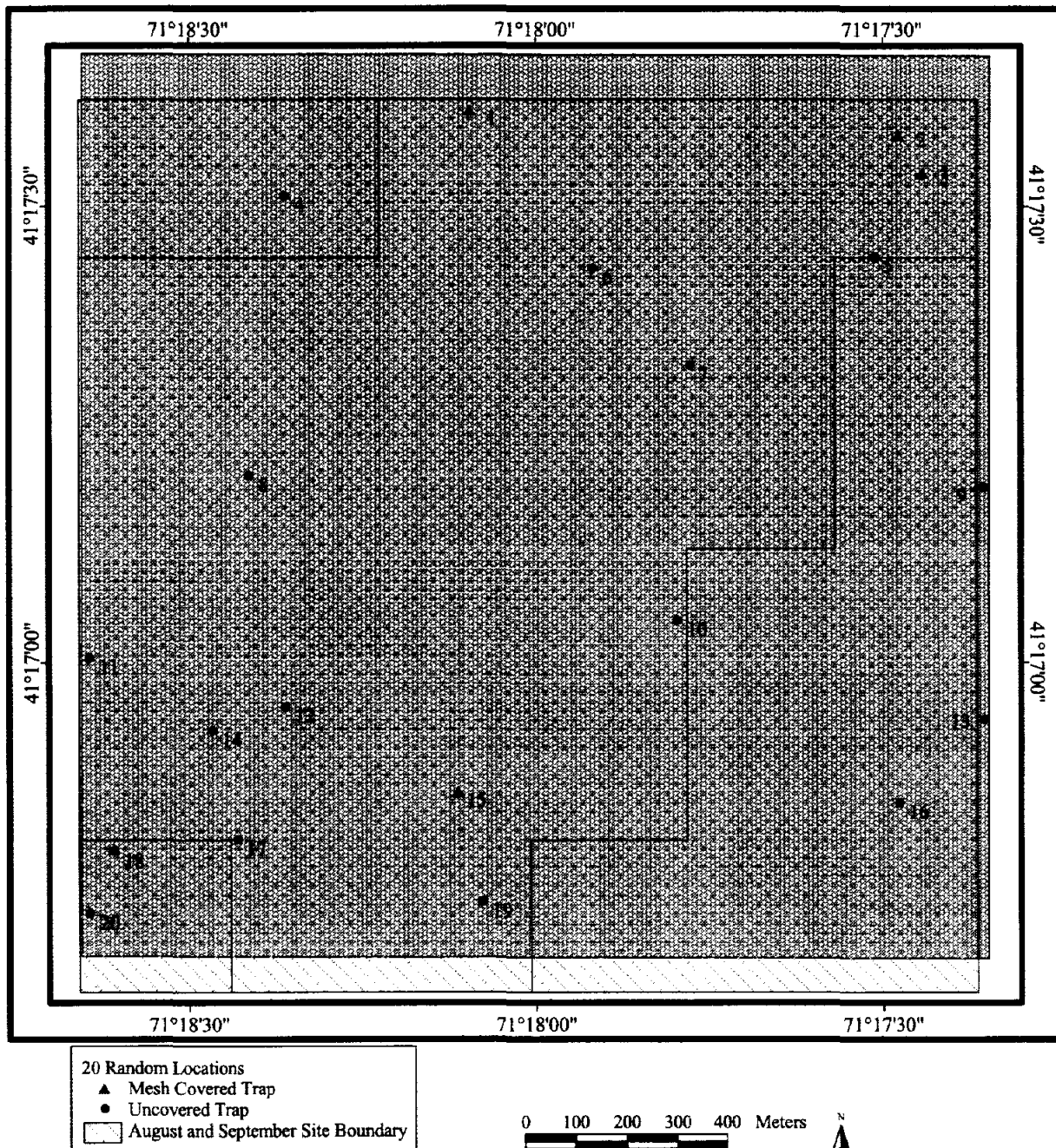


Figure 2(a). Lobster trap placement at Site 69a during the August 1999 sampling event.

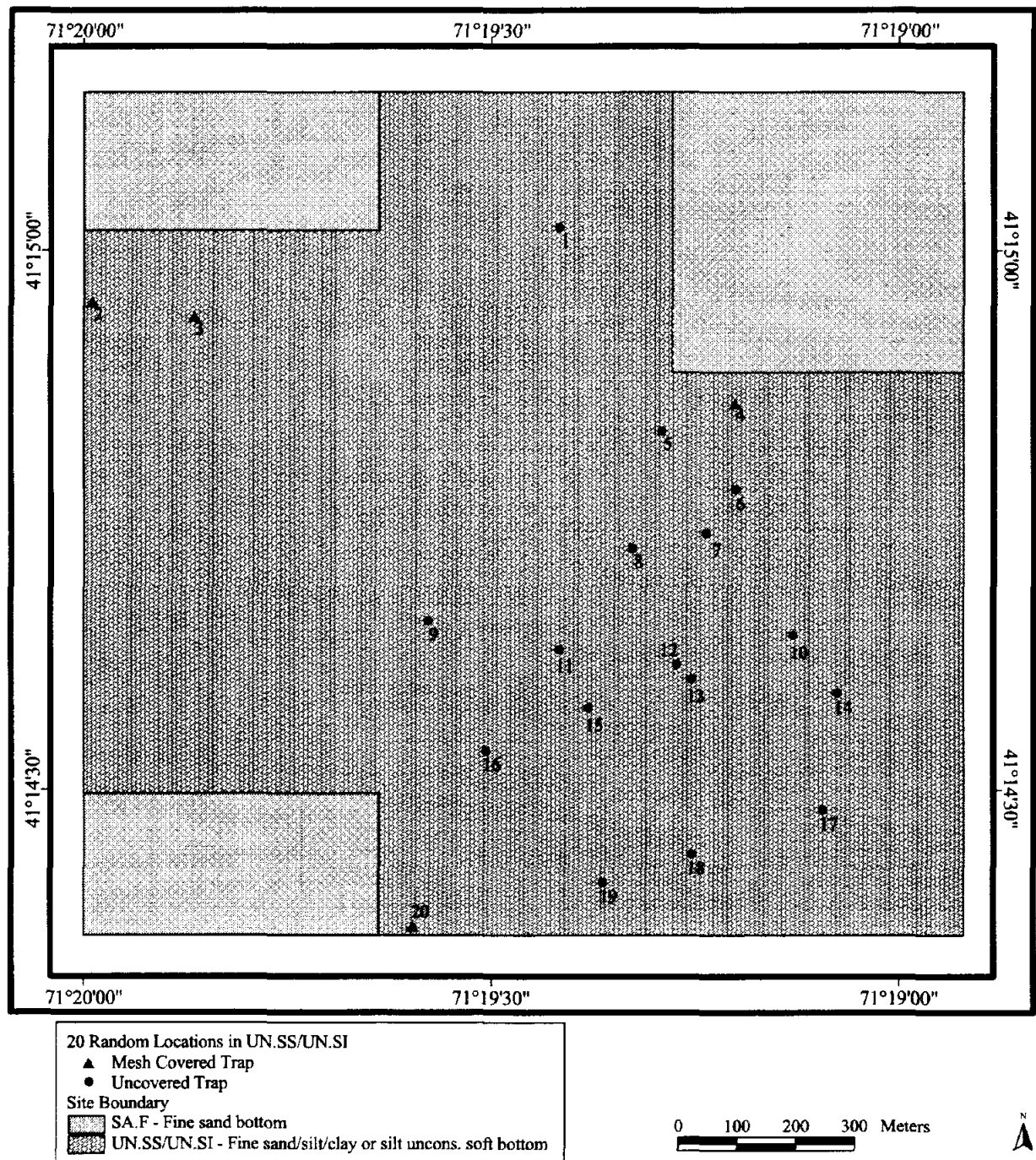


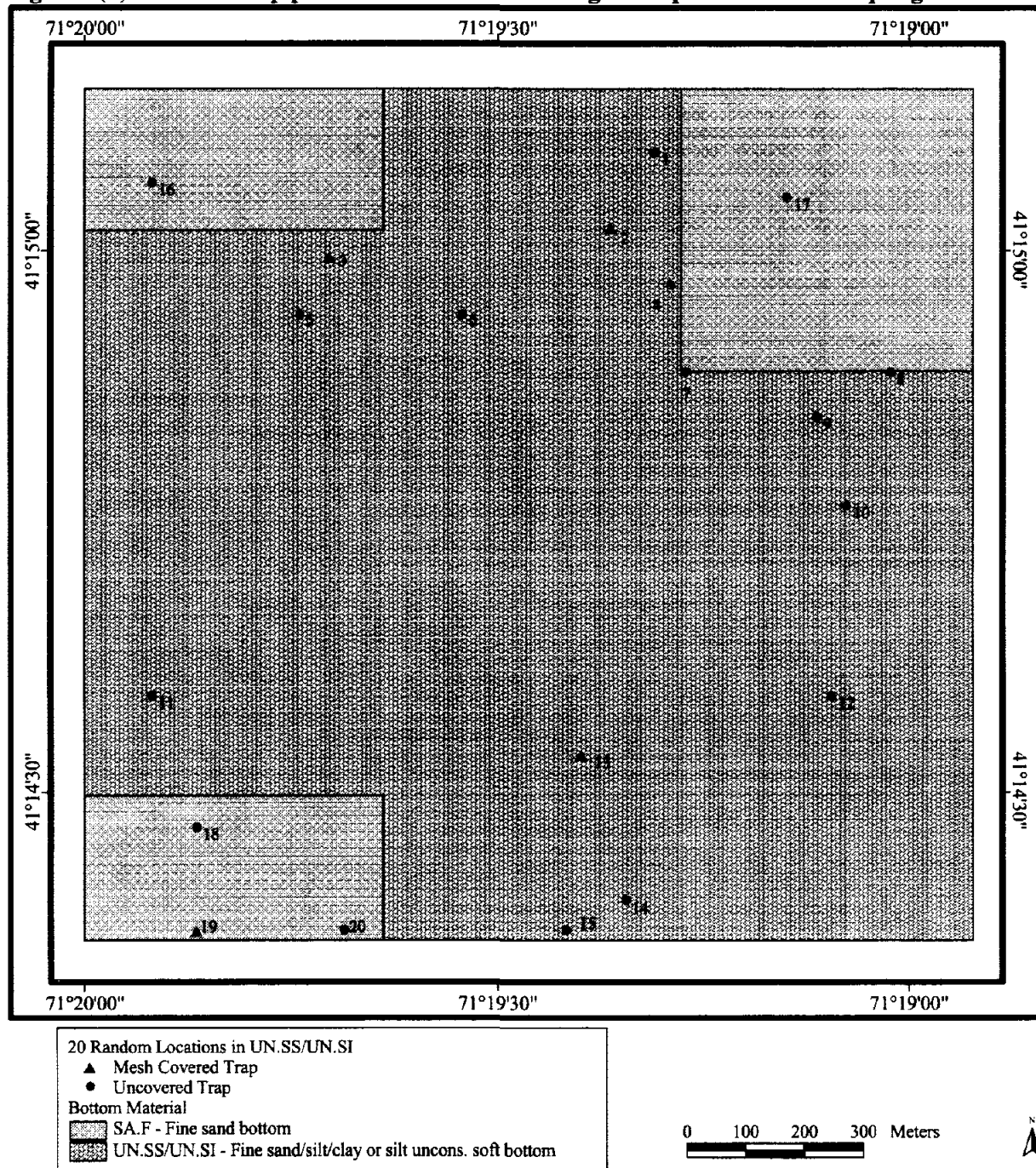
Figure 2(b). Lobster trap placement at Site 69a during the September 1999 sampling event.

Figure 2(c). Lobster trap placement at Site 69a during the November 1999 sampling event. Trap numbers 1, 2, 3, 5, 18, and 20 are outside the original site boundary.

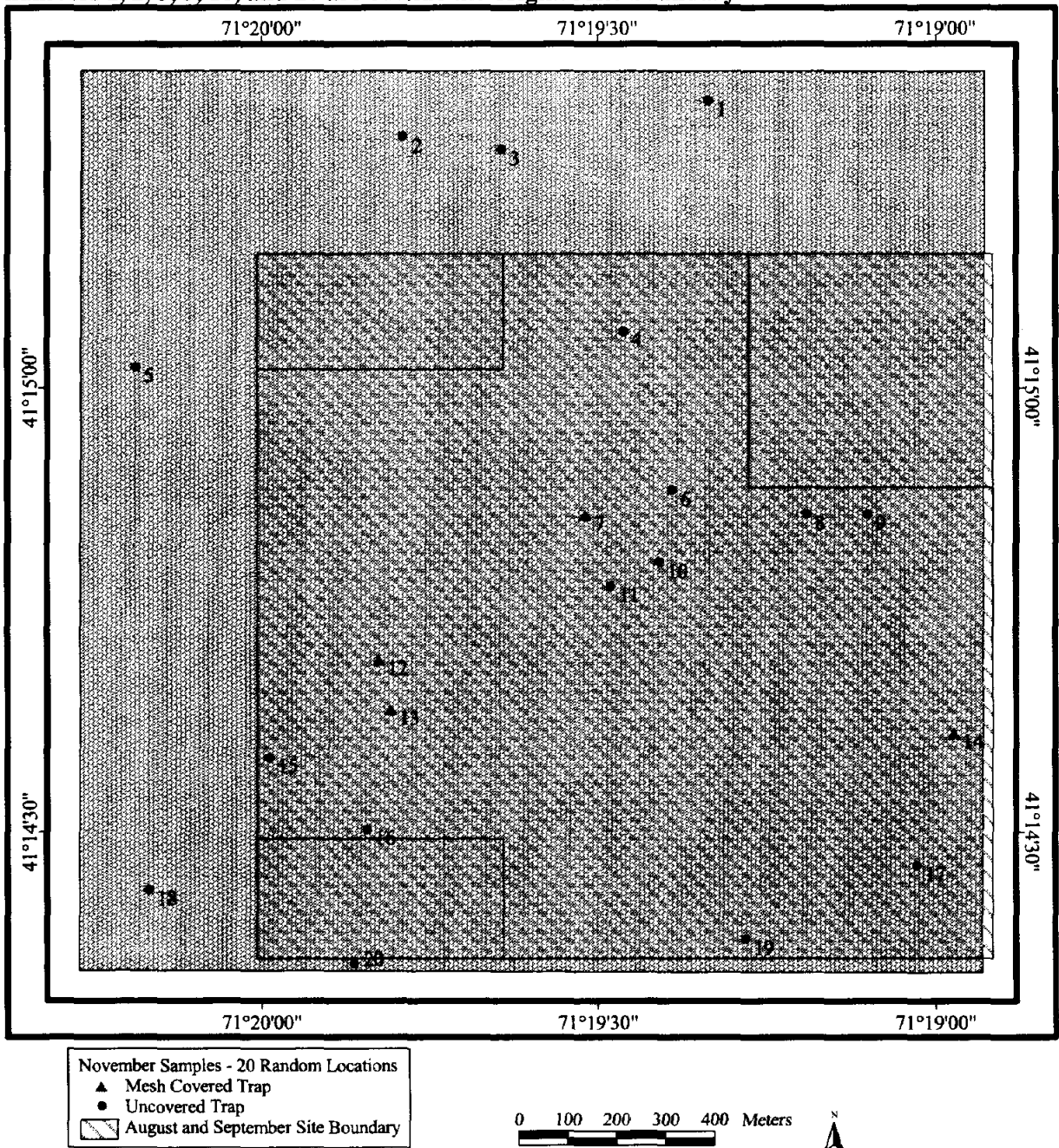


Figure 3(a). Lobster trap placement at Site 69b during the August 1999 sampling event.

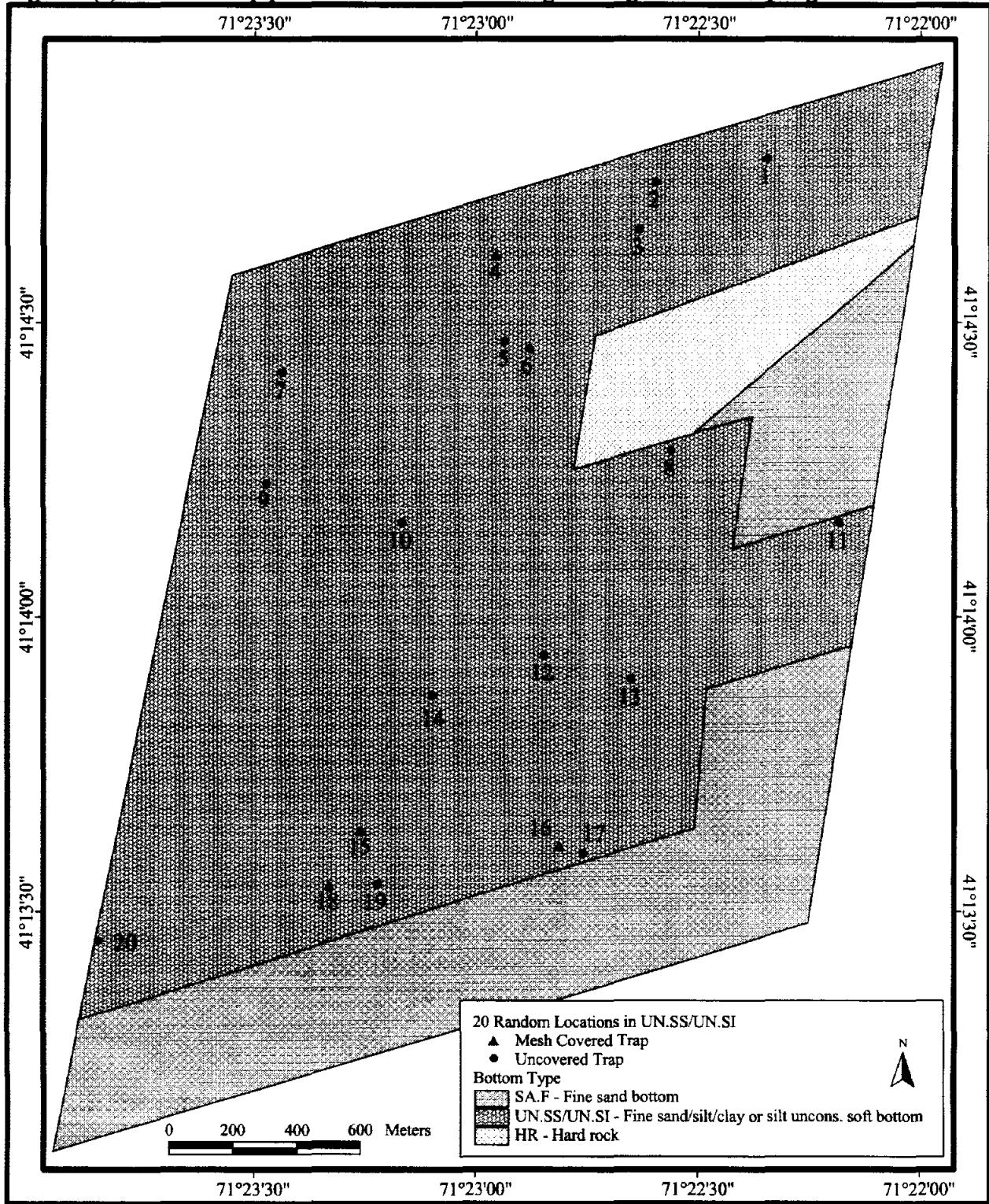


Figure 3(b). Lobster trap placement at Site 69b during the September 1999 sampling event. The shape and aerial extent of Site 69b was changed from the configuration used for the August sampling period.

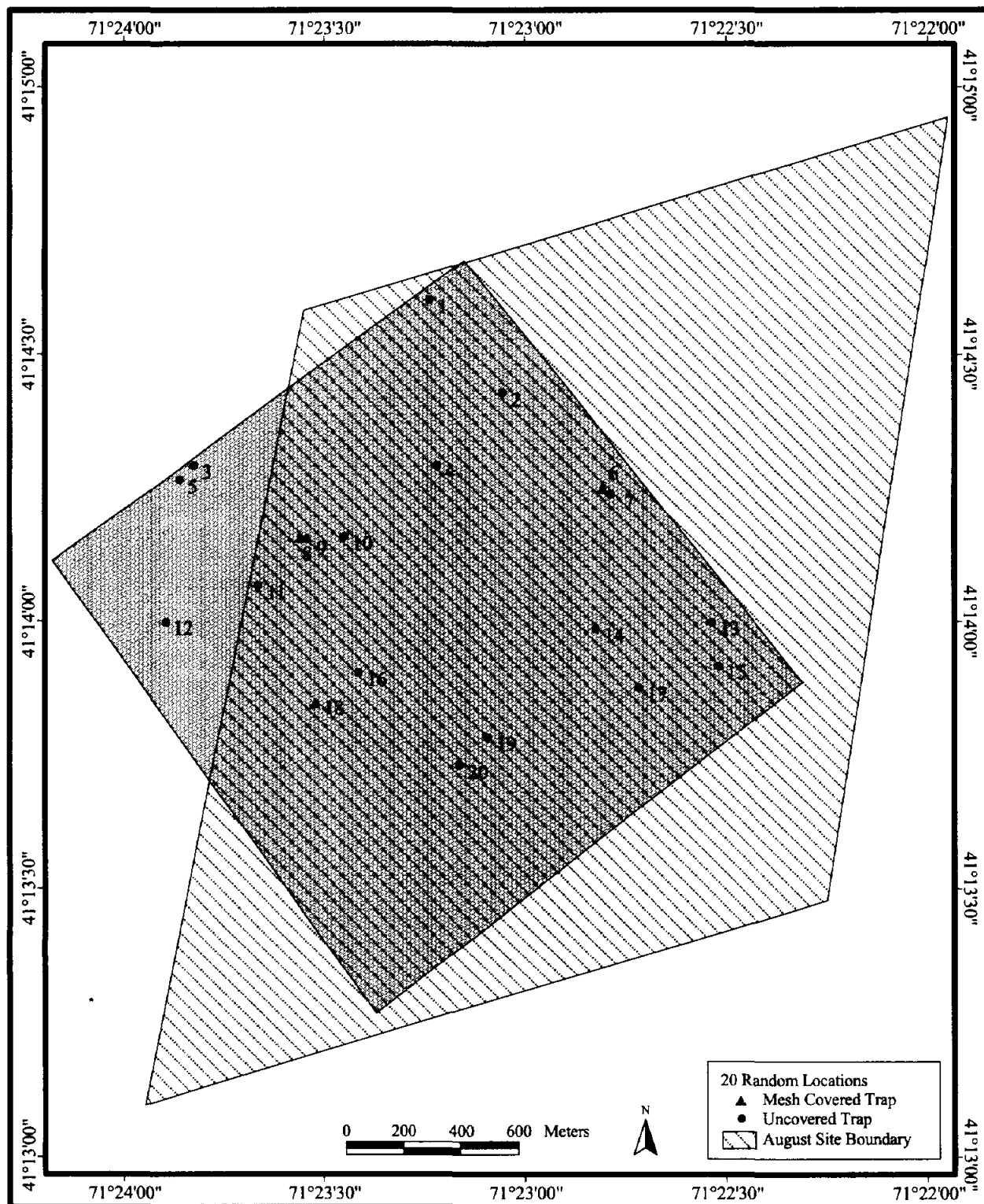
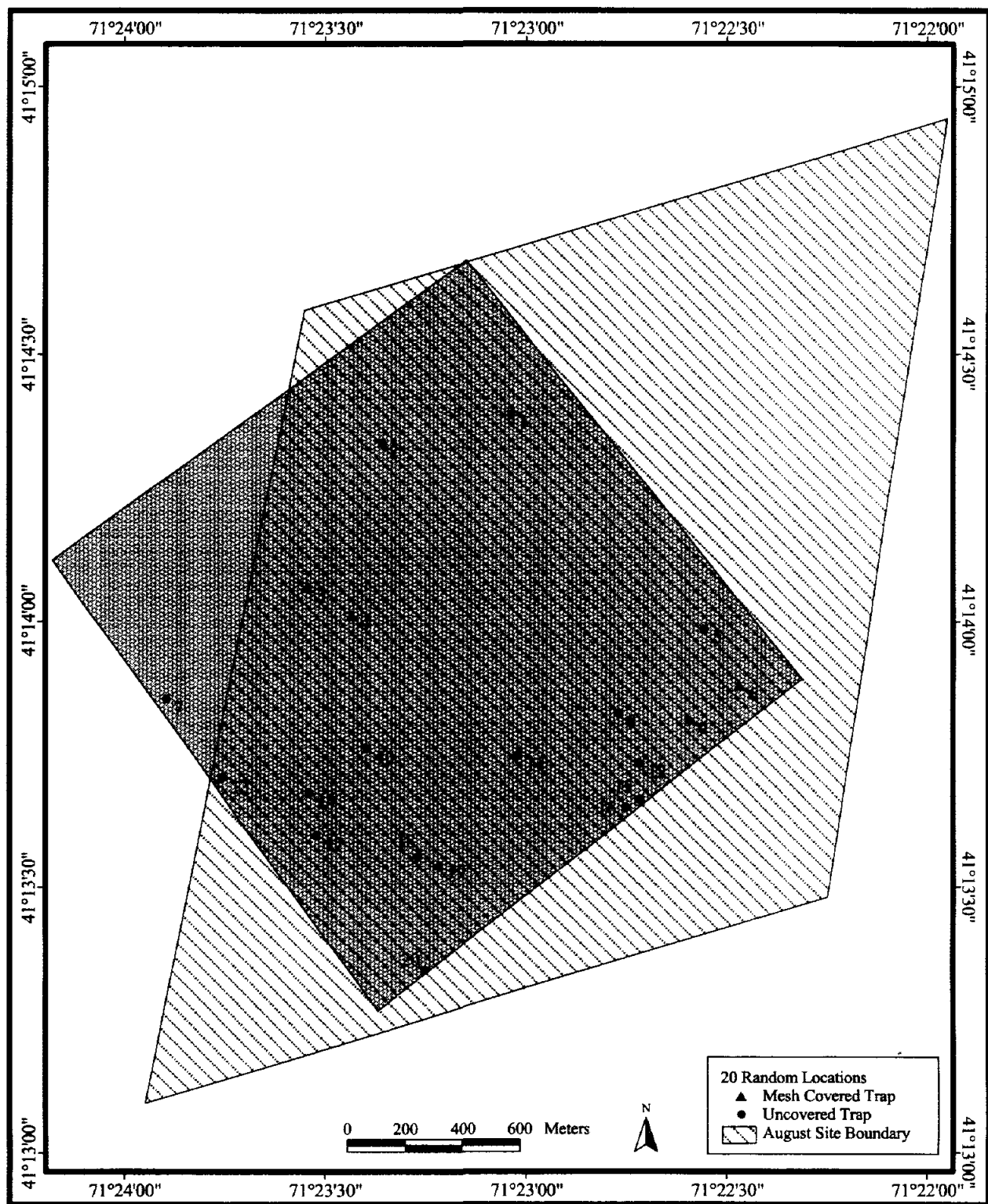


Figure 3(c). Lobster trap placement at Site 69b during the November 1999 sampling event.

3.0 Results and Discussion

Lobsters by Month

The total number of lobsters collected in covered traps, uncovered traps, and the combined total of covered plus uncovered traps at any given site during any given month is shown in Table 4. The mean CPUE of lobsters at a particular site and month is also presented in Table 4. A two-sample t-test indicated that the number of lobsters collected in uncovered traps was not significantly different from the number of lobsters collected in covered traps, when the data were pooled across sites and months ($p > 0.05$).

Regardless of trap type, the largest number of lobsters (877) was collected during August and the fewest lobsters (424 total) were collected during November. Likewise, CPUE of lobsters (both trap types combined) was greatest during the August sampling period at sites 18, 69a, and 69b (mean = 14.9, 17.2, and 11.9, respectively) compared to the September (mean = 8.8, 12.6, 8.9) and November (mean = 7.3, 9.6, 4.8) sampling at those same sites (Table 4; Figure 4). Results of the single-factor ANOVA suggest that the CPUE is significantly different between the three sampling months ($p < 0.001$; Table 5). CPUE during August sampling is significantly greater than CPUE during the September and November sampling periods. The September CPUE is also significantly greater than the CPUE from November.

Table 3. Summary of total number of lobsters collected at a site and mean number of lobsters per trap (CPUE) at a site. Total number of lobsters and CPUE are calculated by trap type for each sampling month.

Month	Trap Type	Site	All Lobsters	
			Total	Mean CPUE
August	Covered	18	47	11.8
		69a	67	16.8
		69b	34	8.5
	Uncovered	18	250	15.6
		69a	276	17.3
		69b	203	12.7
	All Traps	18	297	14.9
		69a	343	17.2
		69b	237	11.9
September	Covered	18	21	5.3
		69a	40	10
		69b	34	8.5
	Uncovered	18	155	9.7
		69a	202	12.6
		69b	143	8.9
	All Traps	18	176	8.8
		69a	242	12.6
		69b	177	8.9
November	Covered	18	26	6.5
		69a	48	12
		69b	14	4.7
	Uncovered	18	120	7.5
		69a	144	9
		69b	72	4.8
	All Traps	18	146	7.3
		69a	192	9.6
		69b	86	4.8

* N = 16 for uncovered traps and N = 4 for covered traps at all sites during all sampling months except Site 69b in November where N = 15 for uncovered traps and N = 3 for covered traps.

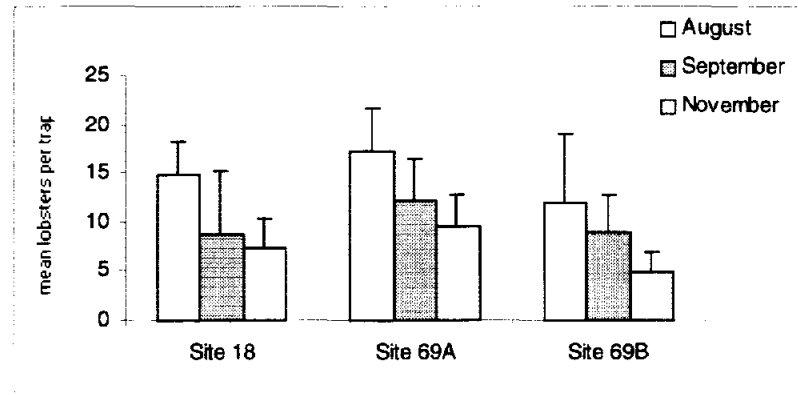


Figure 4. Mean CPUE (\pm std. dev.) of lobsters at Sites 18, 69a, and 69b during the August, September, and November 1999 sampling events. Means are based on all traps (covered + uncovered).

Table 4. Single-factor ANOVA table, evaluating whether the mean number of lobsters/trap (CPUE) varies significantly by month. The mean number of lobsters/trap collected during a particular month is listed below the ANOVA table. Means that share the same letter are not significantly different from each other; means with different letters are significantly different.

<i>Groups</i>	<i>N</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>
August	60	877	14.62	31.49
September	60	595	9.92	26.96
November	58	424	7.31	11.66

ANOVA Table						
<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>p-value</i>	<i>F criteria</i>
Between Groups	1623.22	2	811.61	34.5310	2.29E-13	3.0476
Within Groups	4113.18	175	23.50			
Total	5736.40	177				

Month:	August	September	November
CPUE	14.62	9.92	7.31
	A	B	C

Lobsters by Site

The total number of lobsters collected at any particular site (across months) was greatest at Site 69a. At this site, a total of 777 lobsters was collected over the three sampling events, compared to 619 total lobsters collected at Site 18 and 500 total lobsters at Site 69b. Again, CPUE was greatest at Site 69a during the three sampling periods (mean = 17.2, 12.6, and 9.6) for August, September, and November, respectively (Table 4; Figure 4).

The results from the single-factor ANOVA also suggest that the CPUE of lobsters differs significantly between the three sites ($p < 0.001$; Table 6). The CPUE at Site 18 is significantly different from the CPUE at Site 69a, but is not different from the CPUE at Site 69b. Lobster abundance at Sites

69a and 69b is also significantly different.

Table 5. Single-factor ANOVA table, evaluating whether the mean number of lobsters/trap (CPUE) varies significantly by site. The mean CPUE at a particular site is listed below the ANOVA table. Means that share the same letter are not significantly different from each other; means with different letters are significantly different.

<i>Groups</i>	<i>N</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>		
Site 18	60	619	10.32	30.97		
Site 69a	60	777	12.95	26.01		
Site 69b	58	500	8.62	31.78		
ANOVA						
<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>p-value</i>	<i>F criteria</i>
Between Groups	562.92	2	281.46	9.5207	0.0001	3.047
Within Groups	5173.49	175	29.56			
Total	5736.40	177				
	Site:	Site 69a	Site 18	Site 69b		
	CPUE:	12.95	10.32	8.62		
		A	B	B		

Legal and Sublegal Lobsters

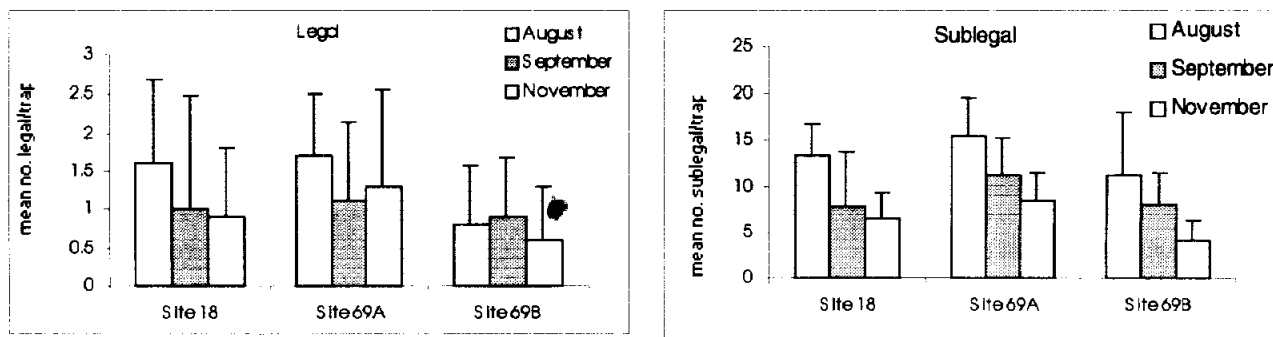
The legal size of lobsters collected from New England waters is 83 mm CL. Table 7 presents the total number, as well as CPUE, of legal and sublegal lobsters at any given site during any given sampling month. Of the 619 lobsters collected at Site 18, 70 lobsters (11%) were \geq 83 mm CL (legal). Of the 777 lobsters collected from Site 69a, 80 (10%) were legal and 43 (8%) of the 500 lobsters collected at Site 69b were legal. On a monthly basis, 81 of 877 lobsters (9%) collected during August were legal, 59 of 595 (10%) collected during September were legal, and 51 of 424 (12%) collected during November were legal. For any given month and site, the greatest number of legal lobsters was collected during August at Site 69a. The fewest number of legal lobsters were collected from Site 69b during the November sampling effort (Figure 5).

Sublegal lobsters, those $<$ 83 mm CL, were more abundant than legal lobsters at all sites and during all three sampling months. The greatest numbers of sublegal lobsters were collected from Site 69a during the August sampling event and the least number of sublegal lobsters were collected during November at Site 69b.

Table 7. Summary of total number and mean CPUE of legal and sublegal-sized lobsters by month, site, and type of trap.

Month	Trap Type	Site	Legal		Sublegal	
			Total	Mean CPUE	Total	Mean CPUE
August	Covered	18	6	1.5	41	10.3
		69a	6	1.5	61	15.3
		69b	2	0.5	32	8
	Uncovered	18	26	1.6	224	14
		69a	28	1.8	248	15.5
		69b	13	0.8	190	11.9
	All Traps	18	32	1.6	265	13.3
		69a	34	1.7	309	15.5
		69b	15	0.8	222	11.1
September	Covered	18	1	0.3	20	5
		69a	3	0.8	37	9.3
		69b	3	0.8	31	7.8
	Uncovered	18	19	1.2	136	8.5
		69a	18	1.1	184	11.5
		69b	15	0.9	128	8
	All Traps	18	20	1	156	7.8
		69a	21	1.1	221	11.1
		69b	18	0.9	159	8.0
November	Covered	18	1	0.3	25	6.3
		69a	5	1.3	43	10.8
		69b	1	0.3	13	4.3
	Uncovered	18	17	1.1	103	6.4
		69a	20	1.3	124	7.8
		69b	9	0.6	63	4.2
	All Traps	18	18	0.9	128	6.4
		69a	25	1.3	167	8.4
		69b	10	0.6	76	4.2

* N = 16 for uncovered traps and N = 4 for covered traps at all sites during all sampling months except Site 69b in November where N = 15 for uncovered traps and N = 3 for covered traps.

**Figure 5. Mean CPUE (\pm std. dev.) of legal and sublegal lobsters collected at Sites 18, 69a, and 69b during the August, September, and November 1999 sampling events.**

Results of a single-factor ANOVA suggest that the CPUE of legal-sized lobsters differs significantly between sites ($p < 0.05$; Table 8), and the CPUE of sublegal-sized lobsters differs significantly between sites ($p < 0.001$; Table 9). CPUE of legal lobsters at Site 18 is not significantly different from the CPUE of legal lobsters at Site 69a, but is significantly different from the CPUE of legal lobsters at Site 69b. CPUE of legal lobsters at Site 69a is also significantly different from the CPUE of legal lobsters at Site 69b. CPUE of sublegal lobsters at Site 18 is not significantly different from the CPUE of sublegal lobsters at Site 69b, and CPUE of sublegal lobsters at both Site 18 and Site 69b are significantly different from CPUE of sublegal lobsters at Site 69a.

Table 8. Single-factor ANOVA table, evaluating whether the mean number of legal lobsters/trap (CPUE) varies significantly by site. The mean CPUE at a particular site is listed below the ANOVA table. Means that share the same letter are not significantly different from each other; means with different letters are significantly different.

<i>Groups</i>	<i>N</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>		
Site 18	60	70	1.2	1.46		
Site 69a	60	80	1.3	1.14		
Site 69b	58	43	0.7	0.58		
ANOVA						
<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>p-value</i>	<i>F criteria</i>
Between Groups	10.949	2	5.474	5.1288	0.0068	3.0476
Within Groups	186.787	175	1.067			
Total	197.736	177				
Site:	Site 69a	Site 18	Site 69b			
CPUE:	1.3	1.2	0.7			
	A	A	B			

Table 9. Single-factor ANOVA table, evaluating whether site location affects the mean number of sublegal lobsters/trap (CPUE) collected during the three sampling periods. The mean CPUE at a particular site is listed below the ANOVA table. Means that share the same letter are not significantly different from each other; means with different letters are significantly different.

<i>Groups</i>	<i>N</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>		
Site 18	60	549	9.2	26.64		
Site 69a	60	697	11.6	22.48		
Site 69b	58	457	7.9	29.02		
ANOVA						
<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>p-value</i>	<i>F criteria</i>
Between Groups	427.703	2	213.851	8.2215	0.0004	3.0476
Within Groups	4551.989	175	26.011			
Total	4979.691	177				
Site:	Site 69a	Site 18	Site 69b			
CPUE:	11.6	9.2	7.9			
	A	B	B			

The CPUE of sublegal-sized lobsters also varies significantly by month ($p < 0.001$; Table 10). The CPUE of sublegal lobsters collected during August is significantly larger than the CPUE of sublegal lobsters collected in either September or November. The CPUE of sublegal lobsters from the September collection is also significantly larger than the CPUE of sublegal lobsters from the November sampling. The CPUE of legal-sized lobsters does not appear to vary significantly by month.

Table 10. Single-factor ANOVA table, evaluating whether the mean number of sublegal lobsters/trap (CPUE) varies significantly by month. The mean CPUE for a particular month is listed below the ANOVA table. Means that share the same letter are not significantly different from each other; means with different letters are significantly different.

<i>Groups</i>	<i>N</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>		
August	60	796	13.3	27.96		
September	60	536	8.9	22.78		
November	58	371	6.4	9.79		
ANOVA						
<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>p-value</i>	<i>F criteria</i>
Between Groups	1428.345	2	714.173	35.1923	1.43E-13	3.048
Within Groups	3551.346	175	20.293			
Total	4979.691	177				
Site:	August	September	November			
CPUE:	13.3	8.9	6.4			
	A	B	C			

Sex Ratio

Table 11 presents the total number of females and males collected at each site during each sampling event. The CPUE of females and males is also reported for each site and sampling month. In general, female lobsters outnumbered males at all sites during the August and September sampling events (60% females to 40% males). In November, the number of females and males was approximately the same at all sites. The largest number of female lobsters was collected from Site 69a in August and the fewest number of females was observed at Site 69b during November (Table 11; Figure 6). The greatest number of males was also collected from Site 69a during August and the fewest were collected from Site 69b during November (Table 11; Figure 6).

Table 11. Summary of total number and mean CPUE of female and male lobsters by month, site, and type of trap.

Month	Trap Type	Site	Female		Male	
			Total	Mean CPUE	Total	Mean CPUE
August	Covered	18	30	7.5	17	4.3
		69a	41	10.3	26	6.5
		69b	21	5.3	13	3.3
	Uncovered	18	148	9.3	102	6.4
		69a	167	10.4	108	6.8
		69b	122	7.6	81	5.1
	All Traps	18	178	8.9	119	6.0
		69a	208	10.4	134	6.7
		69b	143	7.2	94	4.7
September	Covered	18	10	2.5	11	2.8
		69a	28	7	12	3
		69b	20	5	14	3.5
	Uncovered	18	94	5.9	61	3.8
		69a	116	7.3	86	5.4
		69b	85	5.3	58	3.6
	All Traps	18	104	5.2	72	3.6
		69a	144	7.2	98	4.9
		69b	105	5.3	72	3.6
November	Covered	18	14	3.5	12	3
		69a	21	5.3	27	6.8
		69b	6	2	8	2.7
	Uncovered	18	50	3.1	70	4.4
		69a	77	4.8	67	4.2
		69b	38	2.5	34	2.3
	All Traps	18	64	3.2	82	4.1
		69a	98	4.9	94	4.7
		69b	44	2.4	42	2.3

* N = 16 for uncovered traps and N = 4 for covered traps at all sites during all sampling months except Site 69b in November where N = 15 for uncovered traps and N = 3 for covered traps.

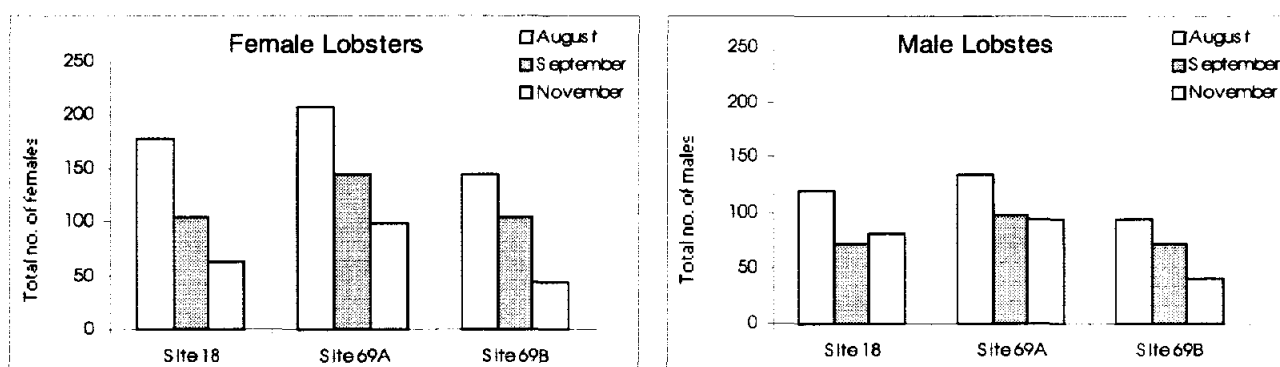


Figure 6. Total number of female and male lobsters collected at Sites 18, 69a, and 69b during the August, September, and November 1999 sampling events.

Of the female lobsters collected, the greatest percentage of gravid individuals was observed during the September and November sampling events. Of the females collected at Site 69a in September, 47% were gravid while, at Sites 18 and 69b, respectively, 34% and 28% of the females collected were gravid. Only 2% of the female catch at Site 69b in August were gravid (Figure 7).

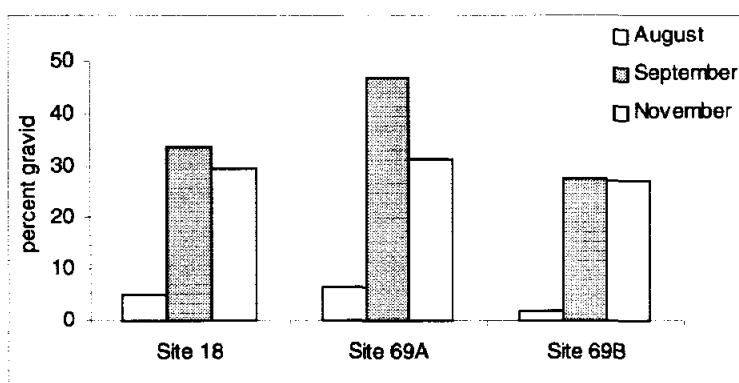


Figure 7. Percent of gravid females observed at Sites 18, 69a, and 69b during the August, September, and November 1999 sampling events.

Lobster Size by Month

Unlike the number of lobster collected per trap, lobster size, as measured in millimeters CL, did vary significantly depending upon type of trap. Lobsters collected in mesh-covered "juvenile" traps were significantly smaller (mean = 76.2) than those collected in uncovered traps (mean = 77; $p = 0.02$). Lobsters collected in uncovered traps were slightly larger than lobsters collected in covered traps at all sites during all sampling periods, except in November at Site 69a when the size of lobsters in covered and uncovered traps was equal (Figure 8).

Lobster size does not differ significantly between sites; however, lobster size does appear to differ significantly between sampling month ($p < 0.001$; Table 12). Lobsters collected in September and November were significantly larger than those collected in August. Mean lobster size did not differ significantly between lobsters collected in September and November.

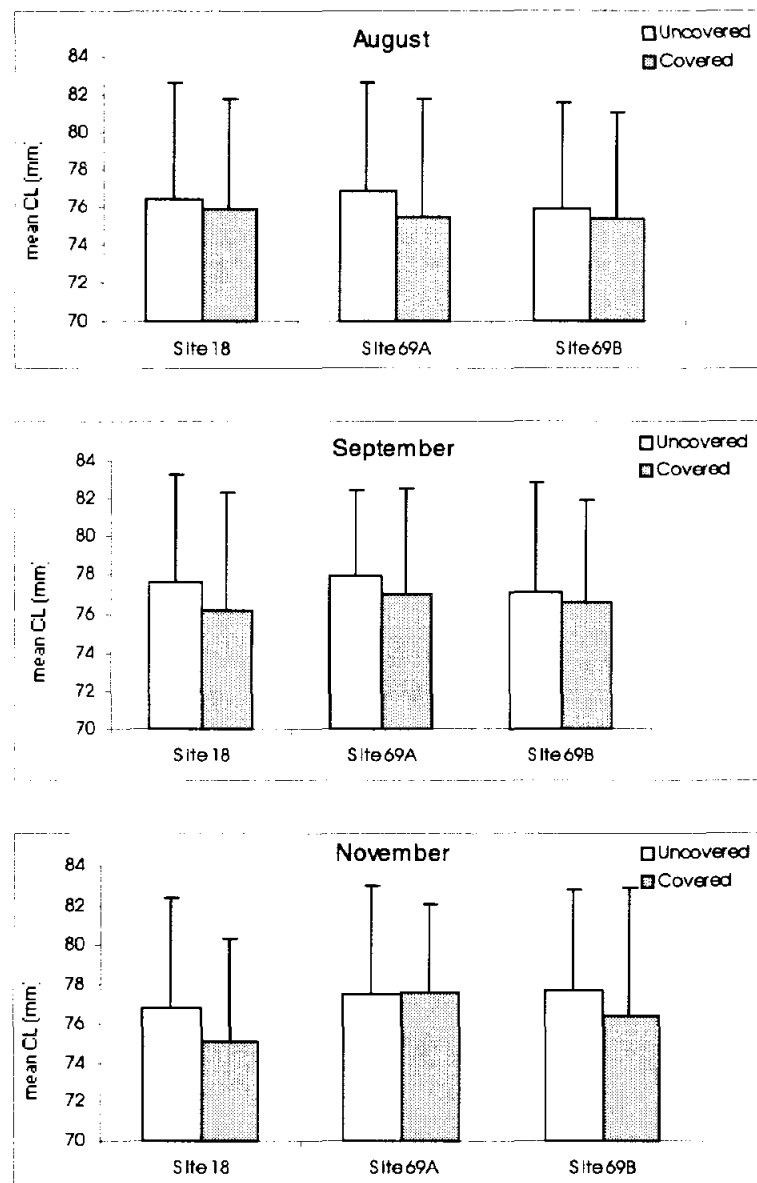


Figure 8. Mean carapace length (\pm std. dev.) of lobsters in mesh-covered traps and uncovered traps at Sites 18, 69a, and 69b during the August, September, and November 1999 sampling events.

Table 12. Single-factor ANOVA table, evaluating whether lobster size varies significantly between sampling months. The mean carapace length of lobsters collected during a particular month is listed below the ANOVA table. Means that share the same letter are not significantly different from each other.

<i>Groups</i>	<i>N</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>		
August	877	66882	76.26	35.40		
September	595	46087	77.46	28.15		
November	424	32712	77.15	29.07		
ANOVA						
<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>p-value</i>	<i>F criteria</i>
Between Groups	560.31	2	280.15	8.8345	0.0002	3.0005
Within Groups	60029.68	1893	31.71			
Total	60589.99	1895				
Month:	September	November	August			
Mean CL:	77.46	77.15	76.26			
	A	A	B			

APPENDIX I-2

SHELLFISH SAMPLING

FOR THE

**PROVIDENCE RIVER AND HARBOR MAINTENANCE DREDGING PROJECT
ENVIRONMENTAL IMPACT STATEMENT**

Submitted to

**Department of the Army
U.S. Army Corps of Engineers
North Atlantic Division
New England District**

**Contract No. DACW33-96-D-0005
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The Draft Environmental Impact Study (DEIS) prepared for the Providence River and Harbor Maintenance Dredging Project presented information about the potential impacts of the project to shellfish resources, including potential impacts to the commercially-important northern quahog, *Mercenaria mercenaria* (a species of clam hereafter called “quahog”). The DEIS summarized earlier studies concerned with population assessments of the quahog, including those of Pratt et al. (1988) and Ganz (1993). Pratt et al. showed that high densities of quahogs could be found to the east of the river channel at the northeast part of Bullock Point Reach and to the east of the channel in Conimicut Point Reach. They also reported high densities of quahogs off Gaspee Point (Bullock Point Reach area) and just north of Conimicut Point (Conimicut Point Reach area). However, most of the tows conducted by Pratt et al. were in relatively shallow areas away from the river channel. Ganz suggested that the Providence River stocks of quahogs were an important source of larvae that could replenish quahog stocks farther down Narragansett Bay.

An additional study of the quahog resource in the Providence River was conducted before preparation of the DEIS. This study, which used divers to sample within relatively small (1m^2) quadrats, focused on the abundance of quahogs within five reaches of the main river channel north of Conimicut Point. This study reported that quahog abundance within the channel was very low, averaging only 0.1 quahog/ m^2 .

Based on literature information and the results of the diver survey, the DEIS concluded (Section 7.3.2.2) that the dredging project would not significantly impact the overall shellfish population north of Conimicut Point, nor would it interrupt larval recruitment to Upper Narragansett Bay by impacting the adult quahog population in the Providence River reaches.

After reviewing the DEIS, the Rhode Island Department of Environmental Management (RIDEM) expressed two concerns regarding the DEIS’ assessment of quahog populations in the Providence River. RIDEM stated first that the DEIS seemed to underestimate the quahog population in the area, particularly along the channel side-slopes (edges of the channel that may slough after dredging), and second, that the project would adversely affect replenishment of quahog stocks in other areas of Upper Narragansett Bay.

In support of the population abundance concern, RIDEM offered data from its own surveys that showed the density of quahogs in the Providence River reaches to be about $9/\text{m}^2$, and stated that a 1998 survey showed that the density of quahogs along the side-slopes of the channel was about $15/\text{m}^2$. RIDEM stated that the use of five small (1m^2) quadrats to sample quahogs was not appropriate because of the characteristic patchy distribution of quahogs.

RIDEM’s concern over impacts to the quahog larval supply were based primarily on the masters degree research of Butet (1997), which is incorporated into an unpublished manuscript (Butet and Rice 1998) that has been updated since the 1996 version cited by RIDEM. RIDEM noted that data from this research showed that larval quahog density was higher in the waters of the Providence River reaches than farther downstream in Narragansett Bay. The contention was that these data, combined with data showing a decreasing adult stock farther down the Bay, meant the Providence River quahog stock was probably the main supplier of larvae that could colonize other parts of Narragansett Bay and that this stock might be adversely affected by the river dredging project.

Because of these concerns raised about the DEIS assessment of quahog populations in the Providence River, a new study, which used standard rocking-chair dredge tows, was conducted to assess quahog densities along the side-slopes of the channel in four river reaches north of Conimicut Point (excluding Fox Point Reach where conditions are not suitable for quahogs) and in Rumstick Neck Reach, an area not previously sampled. The results of this study are reported here.

METHODS

A survey to estimate the abundance of the northern quahog, *Mercenaria mercenaria*, in five Providence River side-slopes areas and selected channel areas was conducted December 14–17, 1999. The University of Rhode Island's research vessel, R/V *Cap't Bert*, served as the sampling platform for this survey. Thirty 3-minute tows were conducted along the channel borders on the side-slopes of the channel at the Rumstick Neck, Conimicut Point, Bullock Point, Sabin Point, and Fuller Rock (south of Fields Point) reaches. Five 3-minute tows were conducted within the channel areas to be dredged in the Rumstick Neck and Conimicut Point Reaches. These two farthest downstream reaches would be most likely to contain quahogs in the base of the channel.

Station Selection

Recent channel sounding charts and plans showing side-slope areas likely to be affected by dredging were used to determine station locations. On the charts of the Providence River reaches, the distance along the channel between the upper and lower borders of each reach was divided into six sections of approximately equal length. The latitude and longitude of each point marking a section was determined. Tow stations were selected randomly from these points. Stations were chosen on the east and west sides of the channel. Ten of the channel border tows were conducted in Rumstick Neck Reach, ten in Conimicut Point and Bullock Point Reaches to 41° 45' N, and ten from 41° 45' N to Fields Point (the remainder were divided between Bullock Point, Sabin Point and Fuller Rock Reaches). A differential global positioning system navigation system, accurate to 3 m, was used to locate stations in the field and to record the start and stop positions.

Water Quality Sampling

Prior to each tow, water temperature, salinity, and dissolved oxygen at the surface and near the bottom was measured with a DataSonde 4 Hydrolab at the start position of each tow. The Hydrolab was calibrated for dissolved oxygen and conductivity according to manufacturers' specification before use.

Dredging Operations

At each station, an 18" wide × 11" high (45.72 × 27.94 cm) rocking-chair dredge was towed for 3 minutes (bottom time) at a speed of approximately 3 knots (resulting tow areas ranged from 75 to 230 m²). The latitude and longitude at the start and end of each tow were recorded manually on field data sheets. Depth was also recorded manually at the start of each tow. In addition, the vessel's position and speed were recorded electronically periodically during the tow. The start and end positions that were recorded electronically were used as the final tow locations.

Dredge Efficiency Tests

Two efficiency tests were conducted approximately 1 km (0.62 mi) northwest of Conimicut Point at about 41° 43.9' N, 71° 22.1' W. Professional Diving Services (PDS) of Newport, RI conducted the dredge efficiency survey. To begin the sampling procedure, the *Cap't Bert* dropped two marker buoys joined by a 100 ft (30.5 m) length of negatively buoyant line. A tow was made across this area parallel to the buoys. An airlift suction sampler (described below) was then lowered at one end (facing into the current). The diver then descended to the suction end and identified the trench made by the dredge. The diver then located the start buoy and proceeded to airlift the trench to a depth of 4" (10.16 cm) recovering all that was in the trench. When the diver reached the end buoy, the airlift was turned off and the diver ascended to the surface. The hopper was then separated from the airlift and towed to the *Cap't Bert* to transfer the sample. The sample was analyzed as described below for the dredge samples.

The trench made by the dredge was obvious to the divers because of the parallel lines scored in the bumpy mud bottom. During the airlifting the diver had to keep his head higher than the cloud forming in front of him. At all times the trench was visible and obvious. The bottom consisted of dark, silty mud.

The dredge appeared to vary in the depth and angle of its bite into the sediment. The cutting depth of the dredge appeared to average 2–5" (50.8–127.0 mm). The observations on the second dive were similar to the first. Current speeds were higher, which allowed for greater visibility.

The airlift suction sampler was a 6" inside diameter (ID) airlift with pipe lengths extending to 55 ft (17 m) overall. There was a 6" ID flex hose at the surface between the collection hopper and the airlift. All joints were made with 6" camlock fittings so that sections could be mated on site. The airlift was powered by a 20 cubic feet per minute (as measured at the surface) gas-powered air compressor. The air was controlled by a 1" brass ball valve at the suction end. The suction end of the airlift was also weighted down with lead. The collection hopper was a 4' x 7' wooden float which contained a 28" x 60" (71.12 x 152.4 cm) 0.5-in-mesh (12.7 mm) galvanized screen in the center of the float with 2 ft (0.61 m) wing walls surrounding. The hopper was somewhat streamlined for ease of towing. The hopper was made buoyant by means of styrofoam billets cut to fit.

Quahog Measurements

The length and width of each quahog in the catch was measured to the nearest millimeter with Vernier calipers. Width was measured as the straight-line distance across the thickest part of each quahog. Length was measured as the straight-line distance from the anterior to the posterior end of the shell at its longest point. If a catch was too large to measure each quahog, then the entire catch was counted and a random subsample of 100 quahogs was measured. Every tenth clam from each catch was re-measured as a quality control check.

Bycatch

The incidental catch of other organisms (termed "bycatch") was noted on the field data sheets. Sediment type and the presence of shell hash, rocks, and cobble also were noted.

Data Analyses

Tow lengths were estimated by using a script within the Geographical Information Systems package ArcView[®] that calculates the distances between two points; in this case, the start and stop positions for each tow. ArcView[®] also was used to plot tow lengths and quahog densities on a chart of the Providence River channel. The area sampled by each tow was then estimated by multiplying the tow length by the metric width of the rocking-chair dredge (0.4572 m). Quahog densities were calculated by dividing the number of quahogs in each tow by the estimated area sampled by the tow.

To permit comparisons with other studies, three size-frequency analyses were run. To compare with Pratt et al. (1988), shell-length frequency was analyzed for pooled river reach samples. The size interval was set at 4 mm. To compare with Gibson (1999), shell-width frequency was analyzed on pooled and individual river reach samples. The size interval was set at 1 mm. To allow comparisons with commercial quahog category data, a size-frequency analysis was conducted for pooled and individual reach data following commercial categories, which are based on shell width measurements, as defined by Ganz (1993). These are: "littlenecks" (25.4–38.1 mm; 1.0–1.5 in), "top necks" (38.1–44.45 mm; 1.5–1.75 in), "cherrystones" (44.45–50.8 mm; 1.75–2.0 in), and "chowders" (>50.8 mm; >2.0 in).

RESULTS

Field Conditions (Water Quality)

The surface and near-bottom water temperature, salinity, dissolved oxygen, and water depth in the vicinity of each tow are listed in Table 1.

Water Temperature

Water temperatures were consistent throughout the study area. Surface waters, which ranged from about 6.4 to 7.9 °C (~43–46 °F) were slightly cooler than near-bottom waters. Near-bottom water temperatures ranged from about 8.3 to 9.9 °C (~47–50 °F).

Salinity

Surface waters in the tow areas were less saline than near-bottom waters. Surface waters ranged from about 23.1 to 30.2 parts per thousand (ppt), whereas near-bottom water salinity ranged from about 30.2 to 32.2 ppt.

Dissolved Oxygen

Surface and near-bottom waters were well oxygenated during the study period. Surface-water dissolved oxygen content ranged from 8.2 to 10.6 mg/L. Near-bottom dissolved oxygen content ranged from 6.7 to 8.4 mg/L.

Quahog Results

Thirty tows were completed along the side-slopes of five Providence River Reaches (Figure 1). Tows were conducted for three minutes and ranged from about 164 to 500 m long (Table 2). Mean \pm one standard deviation tow length per reach ranged from 271.93 ± 76.96 m (Sabin Point) to 336.85 ± 60.45 m (Bullock Point). Five tows were conducted in the river channel, three in Rumstick Neck Reach and two in Conimicut Point Reach. Tows in the channel were similar in length to those in the side-slope regions (Table 2). Estimated areas sampled by individual tows ranged from about 75 to 229 m² (Table 2). The mean \pm one standard deviation estimated area sampled per reach ranged from 124.33 ± 35.19 m² (Sabin Point) to 154.01 ± 27.64 m² (Bullock Point).

Efficiency Test

Two efficiency tests were completed, but yielded somewhat different results. During the first test, the dredge collected 514 quahogs and the divers collected an additional 21 quahogs, yielding a dredge efficiency of about 96%. During the second test, the dredge collected 22 quahogs, whereas the divers collected 38 quahogs, which yielded a dredge efficiency of 37%.

Quahog abundance

Because of the disparity in the results of the two efficiency tests, the raw estimates of quahog abundance and corrected values for each of the efficiency tests are reported in Table 3, but only the uncorrected data are presented in detail.

Quahog abundances on the side-slopes of the Providence River channel were very low throughout all of the reaches. No quahogs were collected from Fuller Rock Reach. Mean (\pm 1 standard deviation) densities among the reaches from which quahogs were collected ranged from 0.10 (\pm 0.10) individuals/m² at Conimicut Point Reach to 0.25 (\pm 0.24) individuals/m² at Sabin Point Reach (Figure 2, Table 4). Mean quahog densities within the channel were very low; 0.07 (\pm 0.11) individuals/m² at Rumstick Neck Reach and 0.05 ($n = 2$) individuals/m² at Conimicut Point Reach (Table 4).

Abundance of quahogs among tows within each reach varied considerably, particularly within Bullock Point Reach (Figure 3, Table 3). The highest quahog densities within the side-slopes of the reaches were

0.68 individuals/m² (Sabin Point Reach, Tow 33W), 0.57 individuals/m² (Rumstick Neck Reach, Tow 11E), and 0.53 individuals/m² (Bullock Point Reach, Tow 28W). Within the channel, the highest abundance for a single tow was 0.20 individuals/m² (Rumstick Neck, Tow RNR5).

Quahog size-frequency

Size-frequency analysis of shell length for all quahogs collected from the Providence River reaches that were sampled showed a weak bimodal distribution with a strong unimodal distribution for size class >52 mm in shell length (Figure 4). The first mode was comprised of relatively few quahogs and showed a peak at a shell length of about 40 mm. The second mode was comprised of the majority of quahogs and showed a peak at a shell length of about 68–76 mm.

Size-frequency analysis of shell width for all quahogs collected from the Providence River reaches that were sampled also showed a possible bimodal distribution (Figure 5). This analysis showed a fairly strong normal distribution for quahogs greater than 32 mm shell width, with a peak frequency at a shell width of about 39 mm. Also noticeable was the sharp reduction in numbers of quahogs having shell widths less than 32 mm. This break most likely reflects the catch restrictions of the dredge rather than any true quahog population measure. With the exception of Rumstick Neck Reach, the general shell width size-frequency pattern revealed by the pooled analysis reflected the patterns found for the individual reaches. For Rumstick Neck Reach, a possible bimodal distribution was suggested, although not strongly (Figure 6).

Size-frequency analysis of shell width according to commercial catch category for pooled data from the sampled side-slopes showed that most quahogs were little necks or topnecks (Figure 7). For pooled data from all reaches, littlenecks accounted for ~49 % and top necks ~38 % of the catch. Few cherrystones (~5 % of the catch) and no chowders were collected. Forty-five sublegal quahogs were collected, most of which (42) were gathered from Rumstick Neck Reach. Again, the pattern for individual reaches was generally similar to the overall pattern, with little necks or topnecks being the most abundant categories.

Bycatch

The bycatch collected by each tow is summarized semi-quantitatively in Table 5. Among the most abundant non-quahog organisms collected were the dwarf surf clam (*Mulinia lateralis*), the blue mussel (*Mytilus edulis*), and seastars (*Asterias* sp.), although each species was very patchily distributed. Several crustaceans were collected, with spider crabs (*Libinia* sp.), blue crabs (*Callinectes sapidus*), and green crabs (*Carcinus maenas*) among the most common. Shell hash was present in most of the tows and was present in larger quantities in the Rumstick Neck and Bullock Point Reaches. Sediments were visually characterized most frequently as mud.

DISCUSSION

Comparison with previous studies

This survey demonstrated that, in contrast to other areas within the Providence River, the side-slopes of the river channel do not support dense stocks of quahogs. The maximum densities reported here (~0.7/m²) were considerably less than the average value (2.3/m²) reported for the Providence River by Pratt et al. (1988) and that reported for recent RIDEM surveys (10.3/m²) by Gibson (1999). The maximum quahog density reported here for Rumstick Neck Reach (~0.6/m²) was substantially lower than the average value (7.3/m²) reported for recent RIDEM surveys of conditional area A, which includes Rumstick Neck Reach (Gibson, 1999).

Within the two reaches sampled (Rumstick Neck and Conimicut Point), quahog densities in the channel floor were lower than those found for the side-slope regions. Additionally, the density of quahogs in the

channel floor of Conimicut Point Reach reported here ($\sim 0.05/\text{m}^2$) was lower than that reported in the DEIS for the diver survey ($0.4/\text{m}^2$), which was the highest channel density found during that survey. The average density of quahogs found in the Rumstick Neck channel base ($0.07/\text{m}^2$) was much less than any value reported in the DEIS for any Providence River reach.

The results of the size-frequency analysis of quahog shell length reported here indicate that the population size structure in late 1999 was similar to that reported in 1988 by Pratt et al. (1988). For pooled Providence River samples, Pratt et al. indicated that shell lengths were unimodally distributed with a peak in frequency at about 72 mm. The present study reported a unimodal distribution with a frequency peak of about 68–76 mm.

The overall shell width size-frequency pattern reported here (unimodal, frequency peak at ~ 39 mm) is similar to results of RIDEM surveys for the Providence River. Gibson (1999) reported that shell widths were unimodally distributed with a frequency peak at about 38 mm. Gibson also provided data on the separation of 1997 RIDEM quahog catches from the Providence River into commercial categories. He reported that, within the Providence River, topnecks ($\sim 35\%$) and cherrystones ($\sim 26\%$) were the most abundant of the commercial categories. He also reported that chowders comprised about 16% of the population in the river. The present study reported somewhat different results as no chowders were found within any of the river reaches and littlenecks were more common than either topnecks or cherrystones. A comparison of the results reported here for Rumstick Neck with Gibson's 1994 RIDEM data from conditional area A, show that in each case littlenecks were predominant. In 1999, topnecks were the second most common category, whereas in 1994 topnecks and chowders were about equally common and ranked second in abundance.

In conclusion, the 1999 survey of the Providence River reaches demonstrates that the channel side-slopes do not have large numbers of quahogs inhabiting them and, therefore, these areas do not represent an important component of the overall quahog population within the Providence River system. In addition, the results of the 1997 survey suggest that the channel bottom does not contain large numbers of quahogs either. Thus, the dredging project will have minimal impacts on the overall quahog population inhabiting the river.

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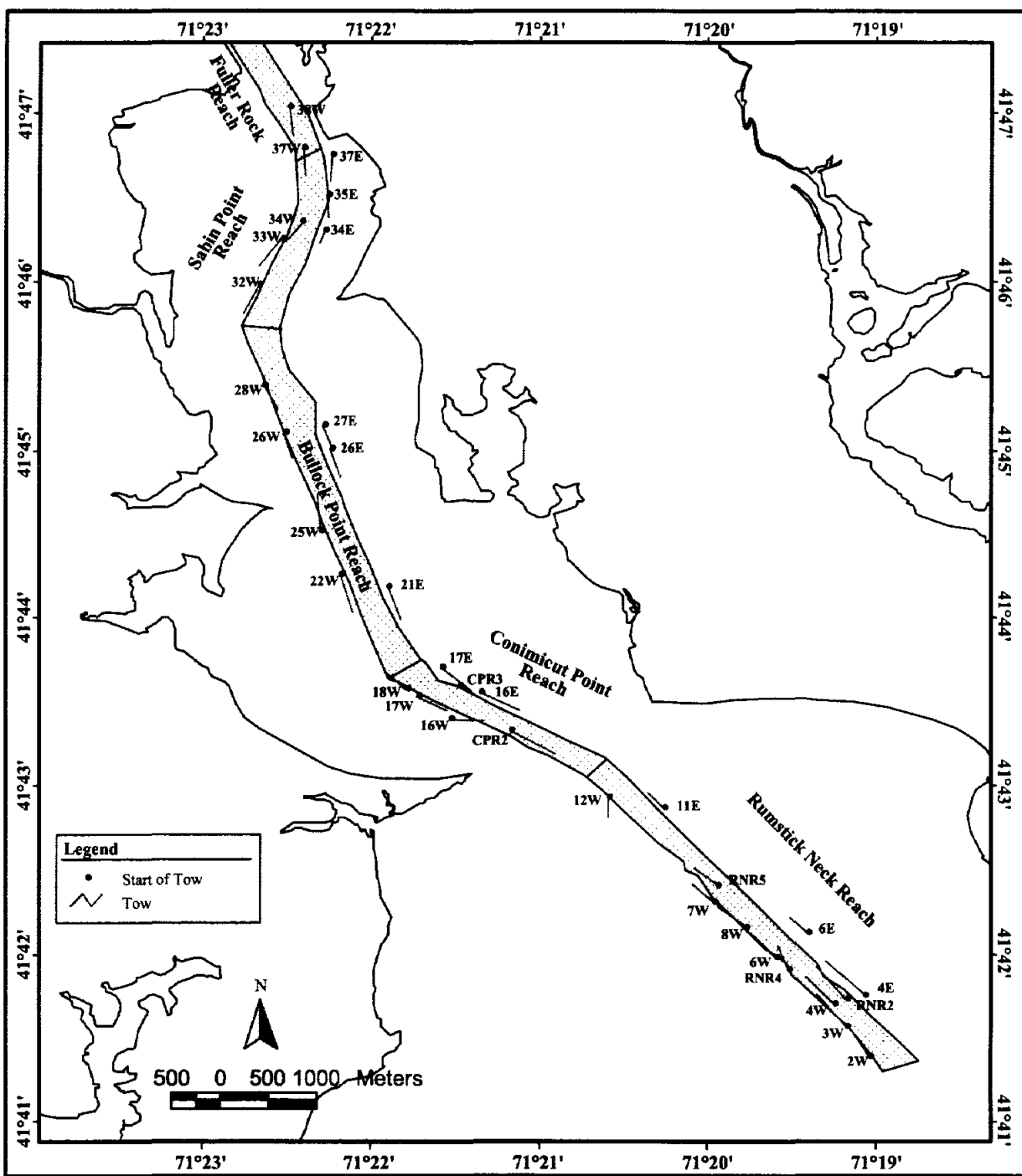


Figure 1. Locations of rocking-chair dredge tows conducted in December 1999. The approximate position of the channel is stippled.

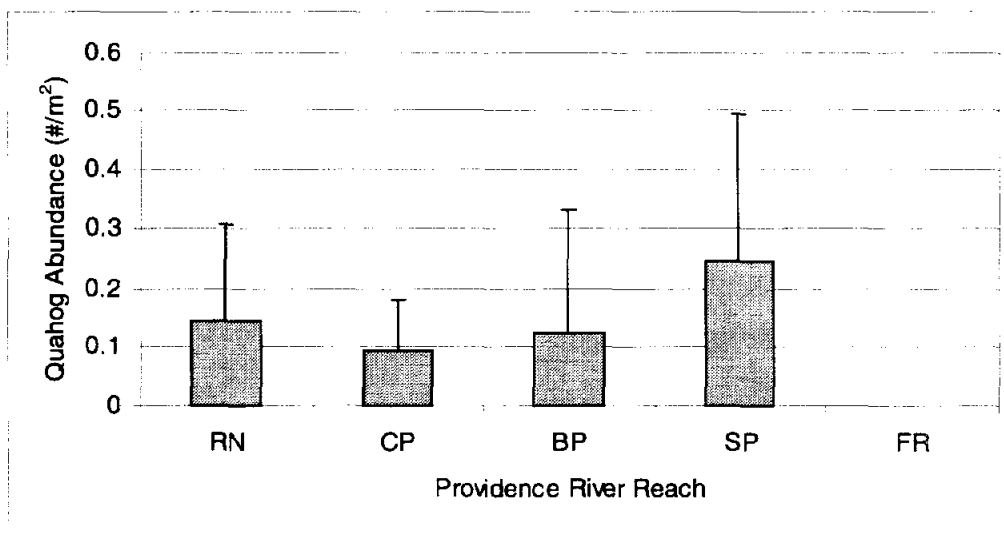


Figure 2. Mean (+standard deviation) quahog abundance in the Providence River reaches, December 1999. RN = Rumstick Neck Reach, CP = Conimicut Point Reach, BP = Bullock Point Reach, SP = Sabin Point Reach, FR = Fuller Rock Reach.

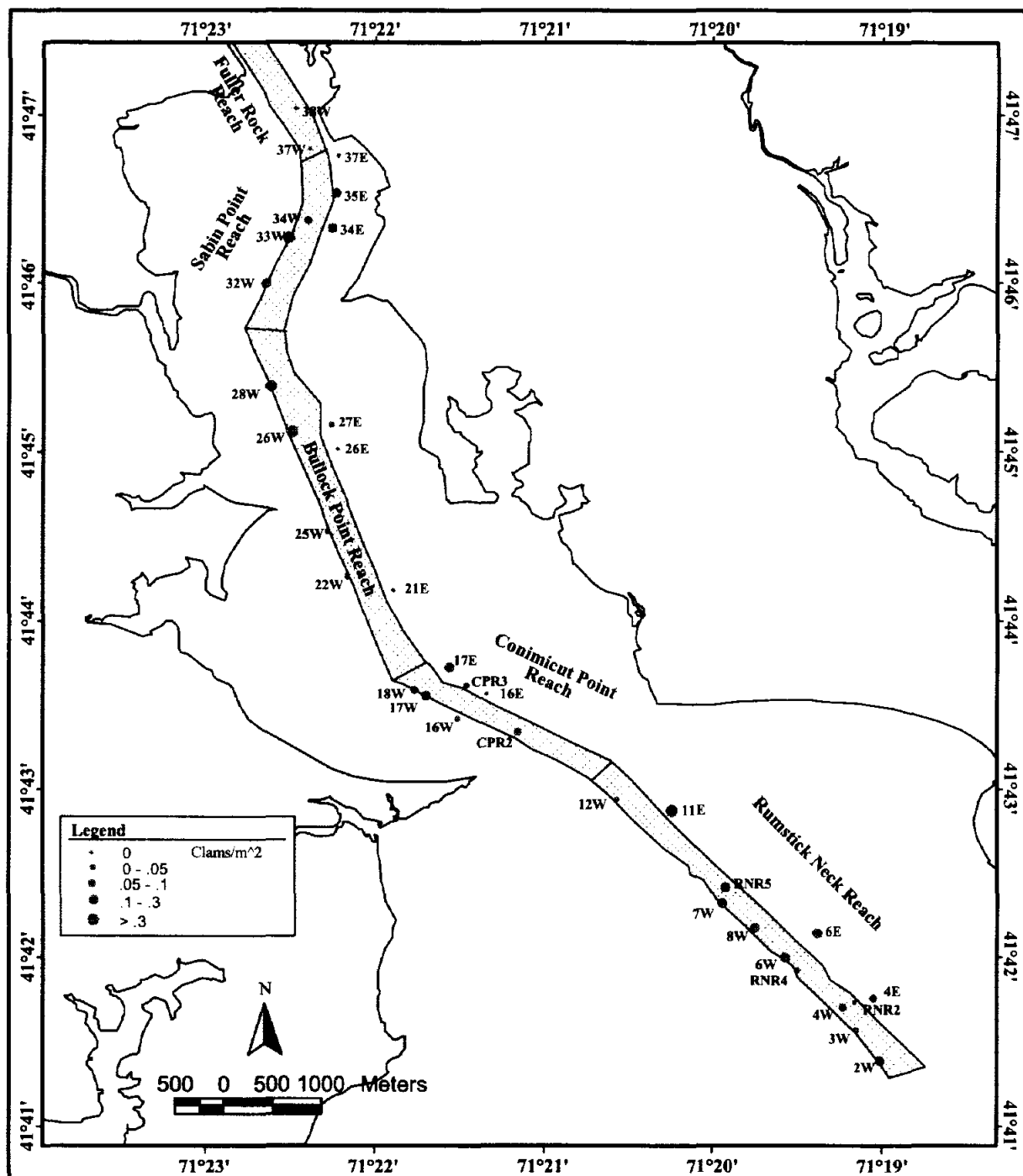


Figure 3. Abundance of quahogs for individual tows conducted in the Providence River reaches, December 1999. Abundance is plotted at the start position of the tow. The approximate position of the channel is stippled.

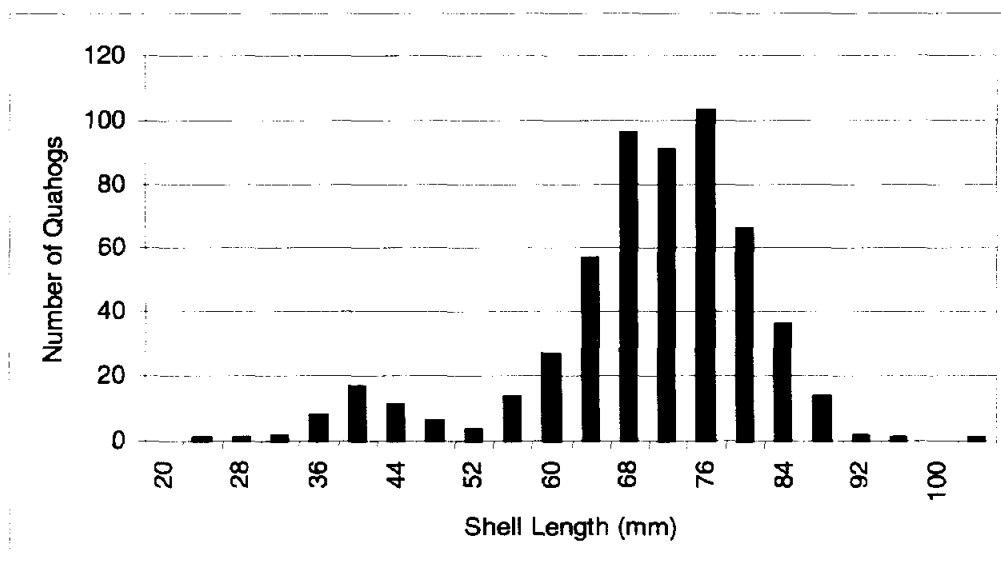


Figure 4. Size-frequency analysis of shell lengths for quahogs collected from the Providence River reaches, December 1999.

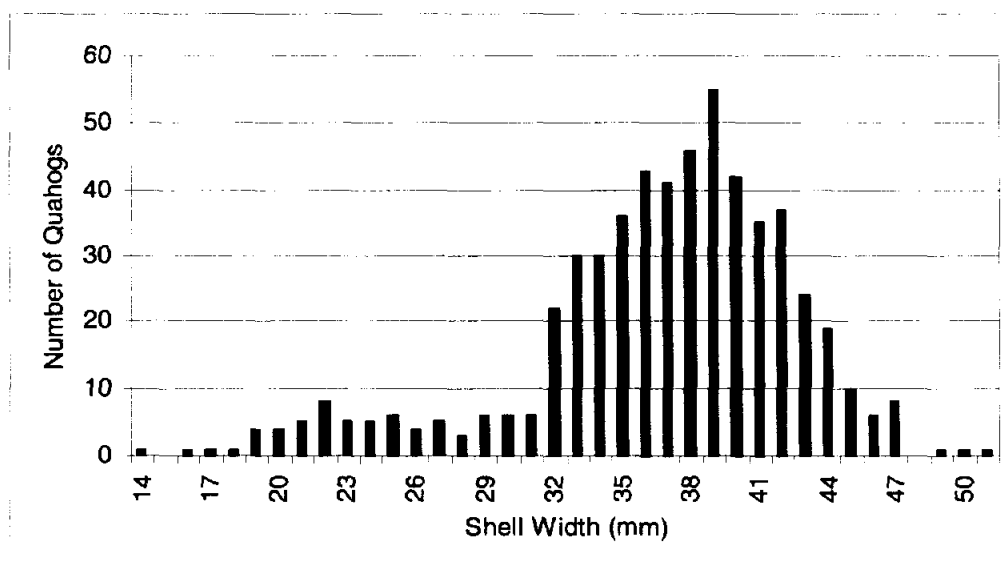


Figure 5. Size-frequency analysis of shell widths for quahogs collected from the Providence River reaches, December 1999.

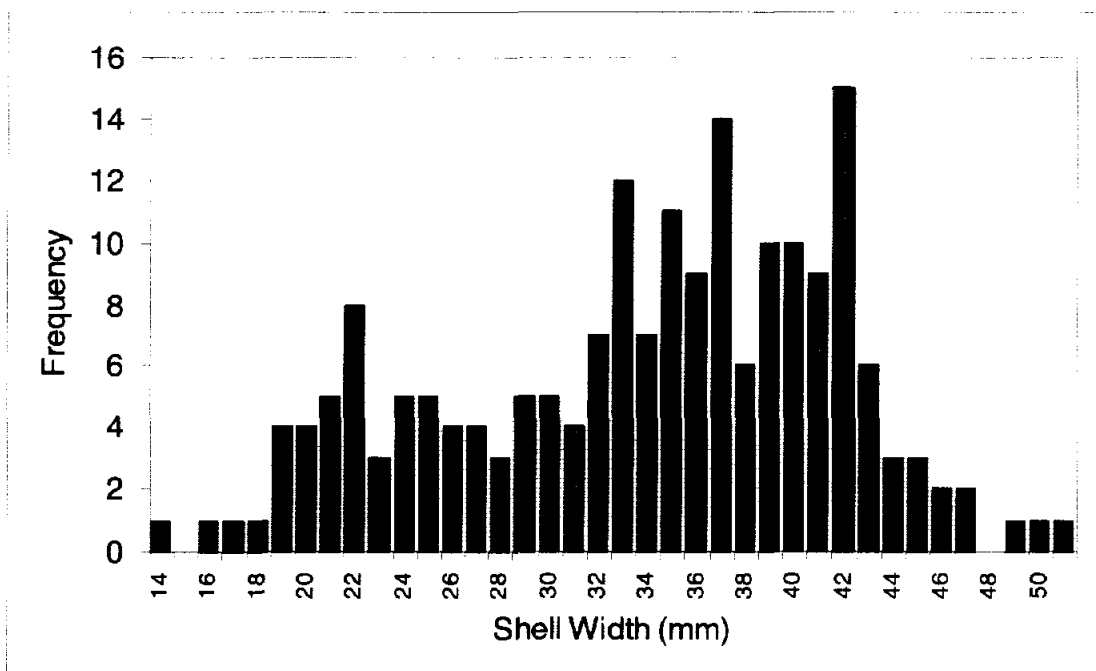


Figure 6. Size-frequency analysis of shell widths for quahogs collected from the Rumstick Neck Reach, December 1999.

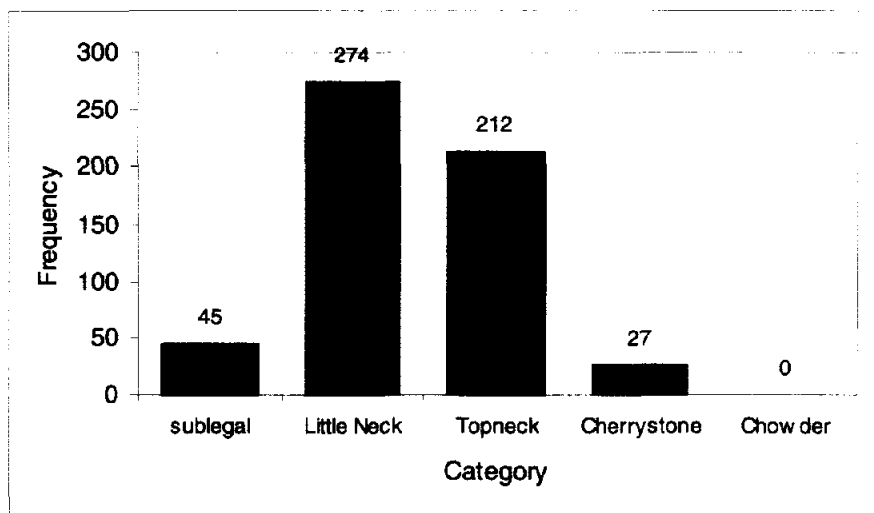


Figure 7. Frequency analysis of commercial size categories of quahogs collected from the Providence River reaches, December 1999.

Table 1. Water quality parameters associated with each rocking chair dredge tow conducted in the Providence River Reaches, December 1999.

Tow #	Water Depth (m)	Temperature (°C)		Salinity (ppt)		Dissolved Oxygen (mg/L)	
		Surface	Bottom	Surface	Bottom	Surface	Bottom
Rumstick Neck Reach Side Slopes							
2W	8.3	7.65	8.65	28.85	30.61	8.50	7.85
3W	7.7	7.58	8.32	29.92	30.93	9.53	8.45
4E	9.8	7.47	9.11	29.84	31.87	9.19	8.15
4W	8.5	7.62	9.26	30.14	31.79	9.56	7.99
6E	10.0	7.65	9.15	27.55	31.94	8.53	7.41
6W	7.3	7.61	8.84	27.54	31.40	8.84	7.48
7W	10.0	7.48	9.03	27.57	31.62	8.64	7.58
8W	8.6	7.56	9.31	26.50	31.23	8.70	7.69
11E	11.0	7.28	9.21	27.63	32.04	8.84	8.06
12W	15.0	7.34	9.06	27.71	31.84	8.91	7.85
Conimicut Point Reach Side Slopes							
16E	12.7	7.38	9.32	25.51	32.10	9.03	7.27
16W	10.5	7.53	9.20	26.34	32.02	8.69	7.43
17E	8.6	6.66	8.55	25.12	31.04	9.62	8.12
17W	10.3	7.55	8.95	28.86	31.68	8.86	7.79
18W	9.8	7.79	8.75	28.19	31.57	8.63	7.75
Bullock Point Reach							
21E	8.4	7.53	8.74	28.08	31.37	8.44	7.44
22W	9.5	7.79	8.70	29.50	31.29	9.40	7.91
25W	8.8	7.25	8.72	27.01	31.45	8.85	7.77
26E	14.5	7.25	9.06	24.15	31.77	8.99	6.73
26W	5.6	7.60	8.64	25.77	31.06	8.40	7.37
27E	8.0	7.71	8.49	26.05	31.01	8.43	7.53
28W	5.9	7.76	8.69	25.72	31.25	8.27	7.38
Sabin Point Reach							
32W	8.5	7.71	8.54	25.87	30.98	8.32	7.38
33W	4.8	7.72	8.53	26.29	30.98	8.48	7.63
34E	10.1	7.65	8.70	27.20	31.30	8.84	7.59
34W	11.0	7.71	8.74	27.02	31.36	8.83	7.59
35E	13.0	7.67	8.78	27.06	31.38	8.24	7.38
Fuller Rock Reach							
37E	15.8	7.75	8.77	28.12	31.21	8.40	7.40
37W	11.0	7.91	8.64	27.75	30.57	8.97	7.64
38W	10.0	7.66	8.66	23.08	30.49	8.85	7.39
Rumstick Neck Channel							
RNR2	15.0	7.58	9.30	30.17	32.07	9.28	7.85
RNR4	15.0	7.36	9.30	30.17	32.20	8.60	7.73
RNR5	14.5	7.44	9.92	29.67	32.13	8.70	7.74
Conimicut Point Channel							
CPR2	10.9	6.38	8.56	23.74	30.20	9.74	8.06
CPR3	13.7	6.49	9.08	24.34	31.72	10.59	7.98

Table 2. Start and end coordinates for rocking chair dredge tows conducted in the Providence River Reaches, December 1999. Tow length and tow area also are included.

Tow	Date	Start Position		End Position		Tow Length (m)	Tow Area (m ²)
		Latitude (° N)	Longitude (° W)	Latitude (° N)	Longitude (° W)		
Rumstick Neck Reach Side Slopes							
2W	12/14/99	41.6896	71.3172	41.6928	71.3195	398.15	182.03
3W	12/14/99	41.6925	71.3194	41.6958	71.3224	439.61	200.99
4E	12/14/99	41.6958	71.3176	41.6992	71.3216	500.36	228.76
4W	12/14/99	41.6948	71.3206	41.6977	71.3235	400.47	183.09
6E	12/16/99	41.7020	71.3233	41.7035	71.3250	225.65	103.16
6W	12/16/99	41.6996	71.3265	41.7019	71.3287	314.80	143.93
7W	12/16/99	41.7049	71.3326	41.7067	71.3347	258.45	118.16
8W	12/16/99	41.7026	71.3294	41.7047	71.3322	327.47	149.72
11E	12/14/99	41.7143	71.3375	41.7158	71.3392	217.15	99.28
12W	12/14/99	41.7153	71.3430	41.7134	71.3430	206.62	94.47
Conimicut Point Reach Side Slopes							
16E	12/16/99	41.7258	71.3556	41.7240	71.3518	376.43	172.10
16W	12/16/99	41.7233	71.3585	41.7229	71.3553	272.27	124.48
17E	12/17/99	41.7283	71.3595	41.7260	71.3565	356.67	163.07
17W	12/17/99	41.7255	71.3618	41.7242	71.3589	282.32	129.08
18W	12/16/99	41.7262	71.3629	41.7279	71.3651	262.55	120.04
Bullock Point Reach							
21E	12/17/99	41.7363	71.3647	41.7330	71.3635	378.81	173.19
22W	12/17/99	41.7374	71.3695	41.7337	71.3683	427.85	195.61
25W	12/17/99	41.7420	71.3714	41.7454	71.3718	387.53	177.18
26E	12/17/99	41.7501	71.3704	41.7473	71.3695	312.77	143.00
26W	12/15/99	41.7517	71.3750	41.7492	71.3742	275.83	126.11
27E	12/15/99	41.7524	71.3712	41.7499	71.3702	296.32	135.48
28W	12/15/99	41.7562	71.3770	41.7539	71.3757	278.82	127.47
Sabin Point Reach							
32W	12/15/99	41.7663	71.3775	41.7635	71.3791	344.23	157.38
33W	12/15/99	41.7709	71.3754	41.7682	71.3775	349.07	159.60
34E	12/15/99	41.7718	71.3711	41.7704	71.3717	164.44	75.18
34W	12/15/99	41.7725	71.3734	41.7706	71.3750	257.33	117.65
35E	12/15/99	41.7752	71.3708	41.7730	71.3708	244.57	111.82
Fuller Rock Reach							
37E	12/15/99	41.7790	71.3704	41.7765	71.3706	275.51	125.96
37W	12/15/99	41.7798	71.3732	41.7772	71.3730	294.29	134.55
38W	12/15/99	41.7838	71.3746	41.7811	71.3742	308.02	140.83
Rumstick Neck Reach Channel							
RNR2	12/14/99	41.6953	71.3195	41.6986	71.3224	437.31	199.94
RNR4	12/14/99	41.6983	71.3253	41.7008	71.3264	296.42	135.52
RNR5	12/14/99	41.7067	71.3323	41.7083	71.3346	262.32	119.93
Conimicut Point Reach Channel							
CPR2	12/17/99	41.7220	71.3526	41.7198	71.3483	433.58	198.23
CPR3	12/17/99	41.7265	71.3577	41.7249	71.3548	299.00	136.70

Table 3. Uncorrected and corrected numbers and densities of northern quahogs collected in the Providence River Reaches, December 1999. Corrected values are based on the results of the two dredge efficiency tests conducted during the survey.

Tow	Uncorrected		Corrected, Test #1		Corrected, Test #2	
	# clams	clams/m ²	# clams	clams/m ²	# clams	clams/m ²
Rumstick Neck Reach Side Slopes						
2W	24	0.13	25.0	0.14	65.4	0.36
3W	10	0.05	10.4	0.05	27.3	0.14
4E	23	0.10	23.9	0.10	62.7	0.27
4W	13	0.07	13.5	0.07	35.5	0.19
6E	11	0.11	11.4	0.11	30.0	0.29
6W	17	0.12	17.7	0.12	46.4	0.32
7W	16	0.14	16.6	0.14	43.6	0.37
8W	19	0.13	19.8	0.13	51.8	0.35
11E	57	0.57	59.3	0.60	155.4	1.57
12W	2	0.02	2.1	0.02	5.5	0.06
Conimicut Point Reach Side Slopes						
16E	0	0.00	0.0	0.00	0.0	0.00
16W	3	0.02	3.1	0.03	8.2	0.07
17E	25	0.15	26.0	0.16	68.2	0.42
17W	30	0.23	31.2	0.24	81.8	0.63
18W	11	0.09	11.4	0.10	30.0	0.25
Bullock Point Reach						
21E	0	0.00	0.0	0.00	0.0	0.00
22W	1	0.01	1.0	0.01	2.7	0.01
25W	1	0.01	1.0	0.01	2.7	0.02
26E	0	0.00	0.0	0.00	0.0	0.00
26W	50	0.40	52.0	0.41	136.4	1.08
27E	4	0.03	4.2	0.03	10.9	0.08
28W	67	0.53	69.7	0.55	182.7	1.43
Sabin Point Reach						
32W	31	0.20	32.2	0.20	84.5	0.54
33W	108	0.68	112.3	0.70	294.5	1.85
34E	12	0.16	12.5	0.17	32.7	0.44
34W	7	0.06	7.3	0.06	19.1	0.16
35E	17	0.15	17.7	0.16	46.4	0.41
Fuller Rock Reach						
37E	0	0.00	0.0	0.00	0.0	0.00
37W	0	0.00	0.0	0.00	0.0	0.00
38W	0	0.00	0.0	0.00	0.0	0.00
Rumstick Neck Reach Channel						
RNR2	0	0.00	0.0	0.00	0.0	0.00
RNR4	3	0.02	3.1	0.02	8.2	0.06
RNR5	24	0.20	25.0	0.21	65.4	0.55
Conimicut Point Reach Channel						
CPR2	17	0.09	17.7	0.09	46.4	0.23
CPR3	2	0.01	2.1	0.02	5.5	0.04

Table 4. Mean abundance of northern quahogs in the Providence River Reaches, December 1999.
 In addition to the mean, the standard deviation (StDev), 95% confidence intervals (CI),
 and coefficient of variation (CV) are provided.

	Rumstick Neck Reach		Conimicut Point Reach		Bullock Point Reach		Sabin Point Reach	
	# clams	clams/m ²	# clams	clams/m ²	# clams	clams/m ²	# clams	clams/m ²
Mean	19.2	0.14	13.8	0.10	17.6	0.14	35.0	0.25
StDev	14.79	0.16	13.26	0.10	28.42	0.22	41.78	0.24
95%CI	9.16	0.10	11.62	0.08	21.05	0.17	36.62	0.21
CV	77	109	96	95	162	163	119	98
	Fuller Rock Reach		Rumstick Neck Channel		Conimicut Point Channel			
	# clams	clams/m ²	# clams	clams/m ²	# clams	clams/m ²		
Mean	0.0	0.00	9.0	0.07	9.5	0.05		
StDev	0.00	0.00	13.08	0.11	10.61	0.05		
95%CI	0.00	0.00	14.80	0.12	14.70	0.07		
CV	0	0	145	148	112	100		

Table 5. Bycatch collected by rocking-chair dredge tows in three Providence River Reaches, December 1999.

		Rumstick Neck Reach										Conimicut Point Reach					Bullock Point Reach							
		2W	3W	4E	4W	6E	6W	7W	8W	11E	12W	16E	16W	17E	17W	18W	21E	22W	25W	26E	26W	27E	28W	
Plants																								
	<i>Ulva</i>																							
	Red/brown algae																							
Animals																								
Porifera (Sponges)																								
Nemertea (ribbon worms)		1															1							
Annelida																								
	Glyceridae	+																						
	<i>Nereis</i>																1							
Arthropoda																								
	Horseshoe Crab (<i>Limulus polyphemus</i>)											3					1							
	Cirripedia (barnacles)	+																						
	Mantis Shrimp (<i>Squilla empusa</i>)											1												
	Spider Crab (<i>Libinia</i> spp.)	1 1															1							
	Green Crab (<i>Carcinus maenas</i>)											3					1							
	Lady Crab (<i>Ovalipes ocellatus</i>)	2																						
	Blue Crab (<i>Callinectes sapidus</i>)	1 1										4 1					1							
	Cancer Crab (<i>Cancer</i> spp.)	1															1							
Mollusca																								
	Slipper Shell (<i>Crepidula</i> spp.)	+	+++			++	+																	
	Whelk (? <i>Busycon</i> sp.)	3																						
	Dwarf Surfclam (<i>Mulinia lateralis</i>)	3	2	20						100s					100s									
	Blue Mussel (<i>Mytilus edulis</i>)	+	+++	24		+	+						+	100s										
	Razor Clam (? <i>Ensis</i>)											1												
Echinodermata																								
	Seastar (<i>Asterias</i> sp.)											3					20-30							
Chordata																								
	Tunicate	+++															+							
	Winter Flounder (<i>Pseudopleuronectes americanus</i>)	1																						
Debris																								
	Shell Hash	+	++	+++	++	++	++		++	+++	+	+	++	+	+	+	+	++	+++	+++	+	+	+	
	Mud	+++	+	++	++	++		+	+	+			+	+	+	+	+	++	+++	+	+	+	+	
	Rocks																+++							
	Gravel																							
	Clay																							

Table 6. Bycatch collected by rocking-chair dredge tows along the side-slopes in two Providence River Reaches and on the channel floor of two reaches, December 1999.

	Sabin Point Reach					Fuller Rock Reach			Rumstick Neck Channel			Conimicut Point Channel	
	32W	33W	34E	34W	35E	37E	37W	38W	RNR2	RNR4	RNR5	CPR2	CPR3
Plants													
<i>Ulva</i>						+++		+++					
Red/brown algae												+	
Animals													
Porifera (Sponges)												+	
Nemertea (ribbon worms)										1			
Annelida													
Glyceridae													
<i>Nereis</i>											++		
Arthropoda													
Horseshoe Crab (<i>Limulus polyphemus</i>)					1								
Cirripedia (barnacles)													
Mantis Shrimp (<i>Squilla empusa</i>)													
Spider Crab (<i>Libinia</i> spp.)													
Green Crab (<i>Carcinus maenas</i>)	1					3		1				2-3	
Lady Crab (<i>Ovalipes ocellatus</i>)												1	
Blue Crab (<i>Callinectes sapidus</i>)				1					1	1			
Cancer Crab (<i>Cancer</i> spp.)											2		
Mollusca													
Slipper Shell (<i>Crepidula</i> spp.)													
Whelk (? <i>Busycon</i> sp.)													
Dwarf Surfclam (<i>Mulinia lateralis</i>)						3							
Blue Mussel (<i>Mytilus edulis</i>)									+		+		
Razor Clam (? <i>Ensis</i>)													
Echinodermata													
Seastar (<i>Asterias</i> sp.)						2		>100			1	++	
Chordata													
Tunicate													
Winter Flounder (<i>Pseudopleuronectes americanus</i>)													
Debris													
Shell Hash	+	+	+	+	+			+			+	+	++
Mud	+	++	+	+	+++	+	+	+		++	+	++	++
Rocks											+		+
Gravel													
Clay			+	+				+		++			++

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Appendix I-3

SEDIMENT PROFILE SAMPLING FOR THE PROVIDENCE RIVER AND HARBOR FINAL ENVIRONMENTAL IMPACT STATEMENT

Submitted to

**Department of the Army
U.S. Army Corps of Engineers
North Atlantic Division
New England District**

**Contract No. DACW33-96-D-0005
Delivery Order No. 0046**

AUGUST 24, 2000

Prepared by

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Figure 13. Maps of habitat types at Site 69a sampling stations in June 1997 and November 1999

Figure 14. Maps of habitat types at Site 69b sampling stations in June 1997 and November 1999

APPENDICES

APPENDIX A: Methods for REMOTS® Image Acquisition and Interpretation

APPENDIX B: REMOTS® Image Analysis Results for Sites 69a and 69b, November 1999

1. INTRODUCTION

A survey involving REMOTS[®] sediment-profile imaging was performed in November 1996 to characterize benthic habitats at nine potential dredged material disposal sites located in Narragansett Bay and Rhode Island Sound (Figure 1). A report submitted in March 1997 describes the results of that November survey (SAIC 1997a). Two additional sites (Sites 69a and 69b) were identified and surveyed in June 1997 (Figure 1). An addendum report submitted in October 1997 describes the results of the June 1997 survey of Sites 69a and 69b (SAIC 1997b). Since the June 1997 survey, the Army Corps of Engineers modified the boundaries of Sites 69a and 69b, which required full sampling coverage of the modified sites. A survey was performed in November 1999 to characterize the previously unsampled areas within each of the sites resulting from the modified boundaries.

This report presents the results of the November 1999 REMOTS[®] sediment-profile imaging survey of Sites 69a and 69b. The objective of the survey was to provide information on the benthic resources and sediments of the two sites and compare the results to those obtained in previous surveys.

2. METHODS

Sites 69a and 69b are both open-water sites located in Rhode Island Sound about 11 miles east of Block Island (Figure 1). Figure 2 illustrates the change in the boundaries of each site. At Site 69a, the revised boundary encloses a 1 nm² area encompassing the original boundary and expanding the site to the north and west (Figure 2). The revised boundary at Site 69b also encloses a 1 nm² area centered slightly to the west of the original sampling grid (Figure 2).

Sampling grids consisting of 18 evenly spaced stations were used in the original June 1997 survey of each site to provide complete spatial coverage (Figure 2). Additional stations were needed in the November 1999 survey to complete the spatial coverage of each site resulting from the changes in the boundaries. Ten new stations were added to Site 69a, and 17 new stations were added to Site 69b (Figure 3). Five of the stations previously sampled at each site were resampled to examine spatial and temporal variability (Figure 3).

The REMOTS[®] sampling took place on November 19, 1999 aboard the M/V *Aquamonitor* operated by Battelle Ocean Sciences, Duxbury, MA. Methods for field operations and image analysis were identical to those described in the original March 1997 report (SAIC 1997a). A detailed description of the methods for sediment-profile image acquisition and interpretation is provided in Appendix A. One- to five-meter vessel positioning accuracy was achieved at each station using a differential-GPS navigation system. The REMOTS[®] camera was lowered at least twice at each station to ensure that at least one image suitable for analysis was obtained. Color slide film was used and developed at the end of the field day to verify proper equipment operation and image acquisition.

3. SURVEY RESULTS

Table 1 provides a description of different benthic habitat types known to be present within Narragansett Bay and Rhode Island Sound based on previous sediment-profile imaging surveys. The survey results for Sites 69a and 69b are presented separately in the following sections.

3.1 Site 69a

At the 15 stations sampled within Site 69a in November 1999, the replicate sediment-profile images obtained in the field were defined as being from the same habitat type (as defined in Table 1), and only one of the replicates was analyzed. A complete set of image analysis results for Site 69a, including the habitat classification for each station, is provided in Appendix B.

There were two habitat types identified at the Site 69a stations: SA.F and UN.SS (Table 2 and Figure 4). The following is a summary of the survey results for each of the habitat types found at Site 69a.

Habitat SA: The SA habitat type consists of hard sand bottoms dominated by bedforms composed of homogeneous sand, with little evidence of bioturbation or shell. The three subhabitat types (SA.F, SA.M, and SA.G, see Table 1) distinguish three different types of sand: SA.F consists of fine sand (3-2 phi), SA.M consists of medium sand (2-1 phi), and SA.G consists of medium to coarse sand with some gravel-size particles (2 to -2 phi). Only SA.F was found among the stations sampled at Site 69a in the present survey; an example of this habitat type is shown in Figure 5. Specifically, this subhabitat type was found in 4 of the 15 images (27%) analyzed at Site 69a (Table 2).

The average penetration depth of the REMOTS® camera prism within the SA.F habitat type was 3.34 cm for the Site 69a stations (Table 3). This is relatively low average prism penetration compared to the maximum possible penetration of 20 cm. This low average value reflects the relative compactness of the sand and is in relatively good agreement with the average penetration for SA.F habitat (4.8 cm) found at the nine sites surveyed in November 1996 (SAIC 1997a). The average depth of the apparent redox potential discontinuity (RPD, a measure of oxygen penetration into the sediment, see Appendix A) within the SA.F habitat type at Site 69a was 3.29 cm (Table 3). Based on numerous previous sediment-profile-imaging surveys conducted by SAIC in New England coastal waters, apparent RPD depths of 3 cm or greater are considered well developed and indicative of deep sediment aeration. The average RPD value of 3.29 cm for habitat SA.F at Site 69a is in good agreement with the overall mean RPD for SA.F (3.5 cm) found in the November 1996 survey (SAIC 1997a). These well-developed redox depths, suggesting good or healthy sediment oxygenation, are probably related to periodic physical reworking of the rippled sand.

The average Organism-Sediment Index (OSI) value of +6 for the SA.F habitat type at Site 69a is intermediate on the OSI scale of -10 (severely degraded benthic habitat quality) to +11 (undisturbed or extremely healthy benthic habitat quality). The intermediate value of +6 is closer to the higher end of the scale and is generally considered indicative of only moderately disturbed overall benthic habitat quality. This intermediate average OSI value reflects the good sediment aeration of the SA.F stations, but these stations were dominated by surface-dwelling, pioneering (Stage I) organisms (Table 3 and Figure 5). The rippled sand comprising the SA.F habitat may experience periodic bedload transport, which represents a source of physical disturbance to the benthic community. Opportunistic organisms having high population turnover rates (*i.e.*, Stage I)

would tend to dominate in such environments. There were no apparent low dissolved oxygen conditions and no sedimentary methane observed in any of the sediment-profile images of habitat SA.F at Site 69a. Therefore, these parameters were not factored into the calculation of the OSI values.

Habitat UN: The three unconsolidated soft bottom habitat types (UN.SS, UN.SI, and UN.SF) are composed of a range of sediment types from very fine sand mixed with silt-clay (UN.SS), to silts (UN.SI), to very soft silt-clay with high apparent water content (UN.SF; see Table 1). Of these three subhabitats, only UN.SS was found among the stations sampled at Site 69a in November 1999 (Figures 4 and 6). Habitat type UN.SS was observed in 11 of the 15 images (73%) analyzed and was clearly the dominant habitat type at Site 69a (Table 2).

The mean prism penetration depth in habitat UN.SS was 5.01 cm at the Site 69a stations (Table 3); this is slightly less than the mean penetration of 6.3 cm for this habitat type at Site 69a in the previous survey (June 1997) and the mean of 7.7 cm for this habitat type at the nine sites surveyed in November 1996. Overall, these values are less than half the potential maximum prism penetration depth of 20 cm. These results suggest that there is a significant degree of compactness to the UN.SS sediments at Site 69a, possibly related to the relatively high apparent proportions of fine sand and silt (*e.g.*, Figure 6) in these unconsolidated sediments.

The overall mean RPD depth was 2.78 cm for habitat UN.SS at Site 69a (Table 3). This is less than the overall mean of 4.6 cm for this habitat type at Site 69a in June 1997 but comparable to the overall mean RPD of 2.6 cm for this habitat type at the nine sites sampled in the November 1996 survey. The mean RPD of 2.78 cm is considered indicative of moderately well developed aeration of the surface sediments comprising the UN.SS habitat type.

Of the 11 stations showing UN.SS habitat at Site 69a, Stage I was dominant at 4 stations, a mixture of Stage I and Stage III (Stage I on III) was observed at 4 stations, and 3 stations had a benthic community that appeared to be transitioning from Stage I to Stage II (Table 3). As described in Appendix A, Stage I consists of opportunistic, surface-dwelling organisms, typically small, tubicolous polychaetes (*e.g.*, Capitellids and Spionids). Stage II typically consists of near-surface dwelling bivalves (*e.g.*, *Nucula* sp) and tubicolous amphipods like *Ampelisca* sp. Stage III consists of larger-bodied, head-down deposit-feeders, whose presence is inferred by feeding voids visible at depth in sediment-profile images. Overall, the UN.SS habitat type at Site 69a had primarily Stage I and II successional stages, with a few stations showing evidence that Stage III organisms were present. The apparent dominance of surface-dwelling, opportunistic Stage I and II organisms may be an indication that the site experiences some periodic physical disturbance (*e.g.*, sediment resuspension by waves and/or currents during high-energy storm events like hurricanes or nor'easters).

The mean OSI value for habitat UN.SS at Site 69a was +7 (Table 3). This value is intermediate on the OSI scale of -10 (severely degraded benthic habitat quality) to +11 (undisturbed or highest possible benthic habitat quality). The value falls toward the higher end of the scale and is generally considered indicative of healthy or only moderately disturbed (*i.e.*, by periodic storm events) benthic habitat quality (see Appendix A). The average OSI of +7 for habitat UN.SS at Site 69a reflects both the moderately well-developed RPD depths at most stations, and a benthic community comprised of both surface-dwelling, opportunistic, Stage I organisms and deeper-dwelling, deposit-feeding, Stage III organisms (Table 3). There were no apparent low dissolved oxygen conditions and no sedimentary methane observed in any of the sediment-profile images

of habitat UN.SS at Site 69a. Therefore, these parameters were not factored into the calculation of the OSI values.

3.2 Site 69b

At 17 of the 22 stations sampled at Site 69b in November 1999, the replicate sediment-profile images obtained in the field were defined as being from the same habitat type (as defined in Table 1), and only one of the replicates was analyzed. At three stations, the replicate images showed slightly different habitat types, reflecting small-scale spatial heterogeneity. At these stations (Stations A2, A27, and A31), both images were analyzed and included in the habitat classification. Stations A32 and A33 at Site 69b also had two images analyzed, because the second image at each of these stations showed unique sediment layering (mud over sand stratigraphy). Therefore, 27 images from the 22 stations sampled at Site 69b were analyzed and classified into the habitat/subhabitat categories described in Table 1. A complete set of image analysis results for Site 69b, including the habitat classification for each station, is provided in Appendix B.

There were three habitat types identified at the Site 69b stations: SA.F, HR, and UN.SS (Table 2 and Figure 7). The following is a summary of the survey results by habitat type at Site 69b.

Habitat SA: Of the three hard sand subhabitat types (SA.F, SA.M, and SA.G; Table 1), only SA.F (fine sand) was found among the stations sampled at Site 69b in the present survey (Figure 7). Specifically, this subhabitat type was found in 4 of the 27 sediment-profile images (15%) analyzed at Site 69b (Table 2).

The average penetration depth of the sediment-profile camera prism within the SA.F habitat type was 4.36 cm at Site 69b (Table 4). Similar to Site 69a, this is a relatively low average penetration depth reflecting the compactness of the sand. This average value is in good agreement with the average penetration for SA.F habitat (4.8 cm) found at the nine sites surveyed in November 1996 (SAIC 1997a). The average apparent RPD depth within habitat SA.F at Site 69b was 3.04 cm (Table 4). As previously indicated, experience has shown that RPD values greater than 3 cm are indicative of well-aerated surface sediments. The average RPD value of 3.04 cm for habitat SA.F at Site 69b in November 1999 is in good agreement with the overall mean RPD for habitat SA.F (3.5 cm) found in the November 1996 survey (SAIC 1997a). These values probably reflect sediment aeration associated with periodic physical reworking (bedload transport) of the rippled sand.

Similar to Site 69a, surface dwelling, opportunistic, Stage I organisms were dominant in the SA.F habitat type at Site 69b (Table 4). These organisms are adapted to the periodic physical disturbance associated with bedload transport of the rippled sand.

The average Organism-Sediment Index (OSI) value for the SA.F habitat type at Site 69b was +5 (Table 4). This is an intermediate value suggesting moderate benthic habitat disturbance, possibly related to periodic bedload transport of the sand associated with high-energy storm events. For the SA.F habitat at Site 69b, the value of +5 reflects both the relatively well developed RPD depths and the dominance of opportunistic Stage I organisms (Table 4).

Habitat HR: This habitat type consists of hard bottom composed of sediments ranging in size from cobbles/boulders to pebbles, resulting in minimal to no penetration of the sediment-profile camera prism. This habitat type was observed in only one of the replicate images obtained at

Site 69b (Station A2, replicate C; Figures 7 and 8). Measured parameters such as the apparent RPD, successional stage, and OSI are generally not measurable in this habitat type due to the lack of penetration into the bottom.

Habitat UN: Of the three unconsolidated soft bottom habitat types (UN.SS, UN.SI, and UN.SF, see Table 1), only UN.SS was found among the stations sampled at Site 69b in November 1999 (Figures 6 and 7). This habitat type was observed in 22 of the 27 images (82%) analyzed at Site 69b (Table 2).

The mean prism penetration depth in habitat UN.SS at Site 69b was 6.94 cm (Table 4); this is comparable to the overall mean penetration of 6.3 cm for this habitat type at Sites 69a and 69b in the previous survey (June 1997) and the mean of 7.7 for this habitat type at the nine sites surveyed in November 1996. Overall, these prism penetration values are less than half the potential maximum penetration of 20 cm, suggesting that the UN.SS sediment at Site 69b is somewhat compact. This may be due to the significant proportion of slightly coarser-grained sediment (*e.g.*, fine sand) mixed with silt-clay at most of the UN.SS stations (*e.g.*, Figure 6). The mean apparent RPD depth was 2.39 cm for habitat UN.SS at Site 69b (Table 4). This value is less than the overall mean of 4.4 cm for habitat UN.SS at Sites 69a and b in June 1997, but comparable to the mean RPD of 2.6 cm for this habitat type at the nine sites sampled in the November 1996 survey. Overall, the value of 2.39 cm is considered indicative of fair to good aeration of the surface sediments.

Of the 22 stations showing UN.SS habitat at Site 69b, Stage I was dominant at 9 stations, Stage I transitioning to Stage II was found at 7 stations, and a mixture of Stage I and Stage III (Stage I on III) was observed at 6 stations (Table 4). As described in Appendix A, Stage I consists of opportunistic, surface-dwelling organisms, typically small, tubicolous polychaetes (*e.g.*, Capitellids and Spionids). Stage II typically consists of near-surface-dwelling bivalves (*e.g.*, *Nucula* sp) and tubicolous amphipods like *Ampelisca* sp. Stages I and II were clearly the dominant successional types at Site 69b (16 of 22, or 73%, of the UN.SS stations exhibited either Stage I only or Stage I going to Stage II). In contrast, Stage I on III was observed at only 27% of the UN.SS stations at Site 69b.

The mean OSI value for habitat UN.SS at Site 69b was +6 (Table 4). As previously indicated, OSI values greater than or equal to +6 are generally considered indicative of healthy overall benthic habitat quality (see Appendix A). The average OSI of +6 for habitat UN.SS at Site 69b is an intermediate value on the full OSI scale of -10 to +11, reflecting the moderately well-developed RPD depths at most stations, and a benthic community comprised mainly of surface-dwelling, opportunistic, Stage I and II organisms (Table 4). Similar to Site 69a, the apparent dominance of Stage I and II organisms may be an indication that the site experiences some periodic physical disturbance (*e.g.*, sediment resuspension by waves and/or currents during high-energy storm events like hurricanes or nor'easters). There were no apparent low dissolved oxygen conditions and no sedimentary methane observed in the images at any of the UN.SS stations at Site 69b. Therefore, these parameters were not factored into the calculation of the OSI values for the UN.SS habitat type.

4. DISCUSSION

General Description of Habitat Conditions at Site 69a, November 1999

Site 69a is located about 13 miles east of Block Island (Figure 1), within a local topographic depression having a depth of about 38 m (125 ft), compared to surrounding depths ranging between 34 and 36 m (112 to 118 ft; all depths from NOAA Chart 13218 as illustrated in Figure 9). Stations along the western and northern edges of the site (based on the new site boundary) had either rippled fine sand habitat (SA.F) and fine sand mixed with considerable silt-clay (UN.SS, Figure 4). These two habitat types are similar and distinguished primarily on the basis of the amount of fines (silt-clay) mixed with the fine sand (see Figures 5 and 6). The re-sampled stations at this site all exhibited UN.SS habitat (Figure 4), largely the same as in the previous (June 1997) sampling and suggestive of a predominantly depositional environment in the topographic depression near the site center. The average RPD value for all the Site 69a stations sampled in the survey was 2.92 cm, and the successional stage was primarily Stage I and II seres, with a few Stage I on III designations. The overall average OSI value for the Site 69a stations was +7, indicative of healthy or only moderately disturbed (*i.e.*, by periodic high energy storm events) benthic habitat quality.

General Description of Habitat Conditions at Site 69b, November 1999

Site 69b is located on the northern tip of a large topographic depression, about 11 miles east of Block Island (Figures 1 and 9). The maximum depth of the depression within the surveyed area is about 39 m (129 ft), compared to a depth of about 34 to 35 m (113 to 118 ft) to the north, east, and south of the surveyed area (Figure 9). One replicate in the northeast of the surveyed area showed hard bottom (HR = cobbles and gravel at station A2, see Figures 7 and 8), possibly corresponding to shallower depths in this area (Figure 9). Likewise, very fine, rippled sand (subhabitat SA.F) was found at the northern- and western-most stations (stations A19, A20, A27, A31), possibly related to shallower depths at these locations near or outside the 120 ft depth contour (Figures 4 and 9). The remaining stations near the center and southern half of the revised Site 69b had unconsolidated soft bottom (UN.SS), suggesting a predominantly depositional environment. There were several Site 69b stations (Stations A25, A27, A28, A31, A32 and A33) that showed a distinct mud-over-sand stratigraphy (Figure 10). The thin surface layer of mud may be the result of a recent depositional event.

The overall average RPD depth for the Site 69b stations was 2.49 cm, and there was a varied mixture of Stage I, I to II and I on III successional seres. The combination of moderately well developed RPD depths and a varied benthic community resulted in an average OSI value of +6 for Site 69b. This is an intermediate OSI value considered indicative of healthy or only moderately disturbed benthic habitat quality.

Comparison of the 10 Stations Sampled in Both 1997 and 1999

In each of the two areas (69a and b), five stations originally sampled in June 1997 were selected at random and re-sampled in November 1999 to determine whether there were any significant temporal changes in benthic habitat conditions. A comparison of the REMOTS[®] results for the two time periods is presented in Table 5. At Site 69b, the habitat designation of UN.SS and the grain size major mode of 4 to 3 phi was unchanged at the five stations. Likewise, these parameters were unchanged at 4 of the 5 stations at Site 69a (Table 5). At Site 69a Station B6, there was a minor change in the habitat designation from SA.F to UN.SS and a corresponding

change in grain size from 3 to 2 phi to 4 to 3 phi. This is considered a minor change because there is much similarity between the SA.F and UN.SS habitat types. The difference between the two years at Station B6 may simply reflect small-scale spatial variability. In general, there were no significant changes in habitat type or grain size at the re-visited stations.

At both sites, the average depth of the RPD at the five re-visited stations was shallower in November 1999 compared to June 1997 (4.06 cm versus 2.60 cm at 69b and 4.07 cm versus 2.33 cm at 69a; Table 5). Although the RPD depths were shallower in 1999, they are still considered indicative of well-aerated surface sediments. The RPD depth can vary seasonally in response to several factors, including the rate of organic loading, dissolved oxygen levels in near-bottom waters, and the degree of aeration of the sediments through bioturbation by infaunal organisms. In general, benthic organisms tend to be more abundant and active during warmer months, and the deeper RPD depths in June 1997 may simply reflect more extensive bioturbation compared to November 1999.

In addition to the shallower average RPD depths, there was a noticeable change in the apparent successional stage at each set of 5 stations between the 1997 and 1999 surveys. The majority of Site 69a and Site 69b stations were characterized by Stage II in June 1997, while Stage I and Stage I on III were the predominant successional stages in November 1999 (Table 5). The Stage II designation was due to the presence of dense aggregations of tubicolous amphipods and polychaete tubes observed at the sediment surface at many stations in June 1997. In November 1999, there were significantly fewer amphipod and polychaete tubes visible at the sediment surface, but a greater number of subsurface feeding voids and burrows signaling the presence of larger infaunal organisms (Stage III). Figures 11 and 12 provide representative examples of the observed changes in the community composition and density of benthic organisms at the sediment surface observed at a significant number of stations (Table 5) between the two surveys.

Such changes are not uncommon; benthic communities typically fluctuate in space and time. In particular, past studies indicate that populations of surface-dwelling tubicolous amphipods (e.g., *Ampelisca* sp, see Figure 11, left) are common in both Narragansett Bay and Rhode Island Sound. For example, Saila *et al.* (1972) described the ambient silty sand bottom surrounding the historic Brenton Reef dredged material disposal site in Rhode Island Sound as "amphipod-dominated bottom." The tube-dwelling species *Ampelisca agassizi* was found to be the dominant taxa on fine sand and silty-sand bottom in this area (Saila *et al.* 1972; U.S. Army Corps of Engineers 1990). Other abundant amphipods reported on the ambient seafloor in Rhode Island Sound near the Brenton Reef disposal site include *Byblis serrata*, *Unciola irrorata*, *Leptocheirus pinguis*, *Orchomenella minuta*, *Rhepoxynius hudsoni*, and *Erichthonius fasciatus* (Saila *et al.* 1972; U.S. Army Corps of Engineers 1990). Estuarine populations of Ampeliscid amphipods (e.g., *A. abdita* and *A. vadorum*) can exhibit large seasonal fluctuations in density, while populations of *A. agassizi* found in the deeper, open waters of Rhode Island Sound can remain dominant over wide areas through replacement of the adult population once a year (U.S. Army Corps of Engineers 1990). However, it has also been noted that small-scale variation in density within beds of *A. agassizi* (observed by divers) and predator foraging can result in high spatial variance in populations of this amphipod (U.S. Army Corps of Engineers 1990). In addition, periodic sediment resuspension and associated removal of surface-dwelling organisms during high-energy storm events would also result in significant temporal and spatial variations in populations. It is reasonable to hypothesize that surface-dwelling amphipods (in particular *A. agassizi*) are common at Sites 69a and 69b, with varying abundance in space and time. The REMOTS® results suggesting a difference in community structure and successional stage

between the June 1997 and November 1999 surveys (e.g., Figures 11 and 12) may simply reflect this varying abundance.

At Site 69a, the average OSI for the five re-sampled stations decreased from +8 to +6 between June 1997 and November 1999, while the average OSI at Site 69b decreased from +9 to +8 between the two years (Table 5). These changes in the average OSI values primarily reflect the shallower RPD depths observed at both sites in the November 1999 survey. However, despite these relatively small decreases in the OSI, the average values for both time periods are considered indicative of healthy or only moderately disturbed (*i.e.*, by infrequent high energy storm events) benthic habitat quality at these sites in the open waters of Rhode Island Sound. The five stations at Sites 69a and 69b sampled in both surveys were characterized by relatively well-developed RPD depths (indicating good sediment aeration) and an apparent diverse benthic community comprised of both surface-dwelling opportunists (Stage I and II) and larger-bodied, infaunal deposit-feeders (Stage III).

Comparison of all Stations Sampled in 1997 and 1999

A second comparison involves examining the survey results for all stations sampled at Sites 69a and 69b in 1997 and 1999 (Tables 6 and 7; Figures 13 and 14). In both years, UN.SS and SA.F were the two dominant habitat types at Sites 69a and 69b (Tables 6 and 7). Most of the stations in each area exhibited UN.SS habitat, which consists of very fine sand mixed with a significant amount of silt-clay. The presence of this significant fine-grained sediment fraction suggests that both areas may be depositional; thin depositional layers of fine-grained sediment also were observed at Site 69b in the November 1999 survey (Figure 10). Very fine sand (4 to 3 phi) was the dominant sediment type observed in both areas (Tables 6 and 7).

At both sites, the RPD depths and successional stages differed between the two years. These differences are the same as those noted above for the five stations in each area sampled in both surveys. At Site 69a, the average RPD depth for all stations decreased from 4.52 cm in 1997 to 2.92 cm in 1999 (Table 6). Likewise, the average RPD depth decreased from 4.10 cm to 2.49 cm at Site 69b (Table 7). There were a significant number of stations in both areas that showed Stage II seres (mainly tubicolous amphipods) present in 1997, while most stations in 1999 lacked Stage II and instead had Stage I or Stage I on III (Tables 6 and 7, see also the representative images in Figures 11 and 12). As noted above, the changes in RPD depth may be due to more active bioturbation during the warmer month of June compared to November at both sites. As previously discussed, the differences in successional stage may reflect natural spatial and/or temporal variations in the abundance of species comprising the benthic community at each site (in particular, the tube-dwelling amphipod *A. agassizi*). The change in the RPD depth is the main factor contributing to the slight decrease in the average OSI from +7 to +6 at Site 69b and from +8 to +7 at Site 69a over the two years (Tables 6 and 7). These are minor changes, and overall the average OSI values reflect healthy or only moderately disturbed benthic habitat quality at these sites in both years.

Comparison of 1996, 1997 and 1999 Results

Sites 18, 20, 21 and 22 are located in the open-waters of Rhode Island Sound in the general vicinity of Sites 69a and 69b (Figure 1). The results of REMOTS[®] sediment-profile imaging surveys performed at these sites in November 1996 can be compared with the results obtained at all of the Site 69a and 69b stations in June 1997 and November 1999, perhaps indicating the importance of time-of-year differences. For the four sites sampled in November 1996, the overall average RPD depth was 3.0 cm and the overall average OSI was +7. The average RPD depths for Sites 69a and 69b were deeper in June 1997 (4.52 cm and 4.10 cm, respectively) compared to November 1999 (2.92 cm and 2.49 cm, respectively), but the November 1999 values are roughly comparable to the November 1996 average for the four other open water sites. Likewise, the overall average OSI value of +7 for the four sites sampled in 1996 is comparable to the values observed at Site 69a and 69b in both 1997 and 1999 (range from +6 to +8). Altogether, these OSI values are indicative of relatively healthy, only moderately disturbed (e.g., by periodic high energy storm events) benthic habitat quality at the open water sites in Rhode Island Sound, including Sites 69a and b.

5. CONCLUSIONS

There were three benthic habitat types identified at the Site 69a and 69b stations sampled in November 1999: SA.F (fine sand bottom), UN.SS (unconsolidated soft bottom consisting of fine sand mixed with silt-clay) and HR (hard rock/gravel bottom). The dominant habitat type, UN.SS, was observed in 73% of the images at Site 69a and 82% at Site 69b. Habitat SA.F was observed in 27% of the images at Site 69a and 15% at Site 69b. Habitat HR was only observed at a single station at Site 69b.

The presence of a significant fine-grained fraction in the surface sediments at Sites 69a and b suggests that both sites may be depositional environments.

The average Organism-Sediment Index values calculated for Sites 69a and 69b based on the November 1999 survey (+7 and +6, respectively) are generally considered indicative of healthy or only moderately disturbed benthic habitat quality. RPD depths were generally well developed and there appeared to be a diverse mixture of Stage I and Stage III benthic organisms.

For the 5 stations in each area that were originally sampled in June 1997 and re-sampled in November 1999, the benthic habitat classification was largely unchanged. Shallower RPD depths were observed at Sites 69a and 69b in November 1999 compared to June 1997, and there were significantly fewer Stage I and II organisms visible at the sediment surface in 1999 compared to 1997.

Despite the observed differences in RPD depth and successional stage between the 1997 and 1999 surveys, there were only minor changes in the OSI. The average OSI values in both years are considered indicative of healthy or only moderately disturbed benthic habitat quality. The results from Sites 69a and 69b in 1997 and 1999 are similar to those obtained in November 1996 at several other candidate disposal sites located in Rhode Island Sound.

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TABLES

Table 1. Description of benthic habitats (based on Diaz 1995).

<p>Habitat AM: <i>Ampelisca</i> Mat Uniformly fine-grained (i.e., silty) sediments having well-formed amphipod (<i>Ampelisca</i> spp.) tube mats at the sediment-water interface.</p>
<p>Habitat SH: Shell Bed A layer of dead shells and shell fragments at the sediment surface overlying sediment ranging from hard sand to silts. Epifauna (e.g., bryozoans, tube-building polychaetes) commonly found attached to or living among the shells. Two distinct shell bed habitats: SH.SI: Shell Bed over silty sediment - shell layer overlying sediments ranging from fine sands to silts to silt-clay. SH.SA: Shell Bed over sandy sediment - shell layer overlying sediments ranging from fine to coarse sand.</p>
<p>Habitat SA: Hard Sand Bottom Homogeneous hard sandy sediments, do not appear to be bioturbated, bedforms common, successional stage mostly indeterminate because of low prism penetration. SA.F: Fine sand - uniform fine sand sediments (grain size: 4 to 3 phi). SA.M: Medium sand - uniform medium sand sediments (grain size: 3 to 2 phi). SA.G: Medium sand with gravel - predominately medium to coarse sand with a minor gravel fraction.</p>
<p>Habitat HR: Hard Rock/Gravel Bottom Hard bottom consisting of pebbles, cobbles and/or boulders, resulting in no or minimal penetration of the REMOTS camera prism. Some images showed pebbles overlying silty sediments. The hard rock surfaces typically were covered with epifauna (e.g., bryozoans, sponges, tunicates)-</p>
<p>Habitat UN: Unconsolidated Soft Bottom Fine-grained sediments ranging from very fine sand to silt-clay, with a complete range of successional stages (1, 11 and 111). Biogenic features were common (e.g., amphipod and polychaete tubes at the sediment surface, small surface pits and mounds, large borrow openings, and feeding voids at depth). Several sub-categories: UN.SS: Fine Sand/Silty - very fine sand mixed with silt (grain size range from 4 to 2 phi), with little or no shell hash. UN.SI: Silty - homogeneous soft silty sediments (grain size range from >4 to 3 phi), with little or no shell hash. Generally deep prism penetration. UN.SF: Very Soft Mud - very soft muddy sediments (>4 phi) of high apparent water content, methane gas bubbles present in some images, deep prism penetration.</p>

Table 2. Distribution of benthic habitat types among stations at Sites 69a and 69b.

Description	n	AM	SH.SI	SH.SA	SA.F	SA.M	SA.G	HR	UN.SS	UN.SI	UN.SF
Site 69a	15	0	0	0	4	0	0	0	11	0	0
Site 69b	27	0	0	0	4	0	0	1	22	0	0

Table 3. Summary statistics for prism penetration depth, RPD depth, Organism-Sediment Index, successional stage and grain size major mode across habitats at Site 69a.

Prism Penetration (cm):								
Habitat	n	Mean	Std Dev	Min	Max			
SA.F	4	3.34	0.47	2.82	3.87			
UN.SS	11	5.01	1.44	3.47	7.87			
RPD Depth in cm (only images where measurable):								
Habitat	n	Mean	Std Dev	Min	Max			
SA.F	4	3.29	0.44	2.86	3.87			
UN.SS	11	2.78	0.88	1.49	4.06			
Organism-Sediment Index (only images where calculated):								
Habitat	n	Mean	Std Dev	Min	Max			
SA.F	4	6	1	5	7			
UN.SS	11	7	3	3	10			
Successional Stage Designation (number of replicates with a particular designation):								
Habitat	n	Indet	I	I to II	II	III	I on III	II to III
SA.F	4		4					
UN.SS	11		4	3			4	
Grain Size Major Mode in phi units (number of replicates with a particular designation):								
Habitat	n	<-1	4 to 3	>4				
SA.F	4		4					
UN.SS	11		11					

Table 4. Summary statistics for prism penetration depth, RPD depth, Organism-Sediment Index, successional stage and grain size major mode across habitats at Site 69b.

Prism Penetration (cm):								
Habitat	n	Mean	Std Dev	Min	Max			
HR	1	0.13	0.00	0.13	0.13			
SA.F	4	4.36	1.35	3.21	6.29			
UN.SS	22	6.94	1.80	4.39	10.61			
RPD Depth in cm (only images where measurable):								
Habitat	n	Mean	Std Dev	Min	Max			
HR	na	na	na	na	na			
SA.F	4	3.04	1.53	1.51	4.85			
UN.SS	22	2.39	1.20	0.93	4.55			
Organism-Sediment Index (only images where calculated):								
Habitat	n	Mean	Std Dev	Min	Max			
HR	na	na	na	na	na			
SA.F	4	5	2	4	7			
UN.SS	22	6	2	3	10			
Successional Stage Designation (number of replicates with a particular designation):								
Habitat	n	Indet	I	I to II	II	III	I on III	II to III
HR	1	1						
SA.F	4		4					
UN.SS	22		9	7			6	
Grain Size Major Mode in phi units (number of replicates with a particular designation):								
Habitat	n	<-1	4 to 3	>4				
HR	1	1						
SA.F	4		4					

Table 5. Comparison of various REMOTS parameters for the 1997 stations that were resampled in 1999.

STATION	Habitat type		Grain Size Major Mode		Prism penetration (cm)		RPD depth (cm)		Successional stage		OSI	
	06/17/97	11/19/99	06/17/97	11/19/99	06/17/97	11/19/99	06/17/97	11/19/99	06/17/97	11/19/99	06/17/97	11/19/99
A2	UN.SS	UN.SS	4 to 3	4 to 3	4.74	8.39	3.11	2.29	ST_II	ST_I_ON_III	8	9
A3	UN.SS	UN.SS	4 to 3	4 to 3	8.05	10.16	3.39	1.80	ST_II	ST_I_ON_III	8	8
A5	UN.SS	UN.SS	4 to 3	4 to 3	6.21	7.03	6.29	3.10	ST_II	ST_I_ON_III	9	10
A10	UN.SS	UN.SS	4 to 3	4 to 3	7.06	8.37	3.79	3.25	ST_II_ON_III	ST_I	11	6
A11	UN.SS	UN.SS	4 to 3	4 to 3	10.17	10.03	3.71	2.55	ST_II	ST_I_TO_II	8	6
Average					7.25	8.80	4.06	2.60			9	8
Std Deviation					2.04	1.31	1.28	0.59			1	2
Minimum					4.74	7.03	3.11	1.80			8	6
Maximum					10.17	10.16	6.29	3.25			11	10
B2	UN.SS	UN.SS	4 to 3	4 to 3	6.13	6.61	4.92	1.94	ST_II	ST_I_TO_II	9	5
B6	SA.F	UN.SS	3 to 2	4 to 3	3.97	6.66	4.09	2.03	ST_I	ST_I	7	4
B11	UN.SS	UN.SS	4 to 3	4 to 3	6.79	7.87	4.44	3.12	ST_II	ST_I_ON_III	9	10
B15	UN.SS	UN.SS	4 to 3	4 to 3	1.79	3.47	1.98	3.07	ST_I	ST_I_ON_III	4	10
B18	UN.SS	UN.SS	4 to 3	4 to 3	7.18	3.47	4.94	1.49	ST_III	ST_I	11	3
Average					5.17	5.62	4.07	2.33			8	6
Std Deviation					2.26	2.02	1.22	0.73			3	3
Minimum					1.79	3.47	1.98	1.49			4	3
Maximum					7.18	7.87	4.94	3.12			11	10

Table 6. Comparison of 1997 versus 1999 REMOTS results (all stations at Site 69a).

Station	Rep.	Habitat type		Successional stage		Grain size major mode		Penetration depth (cm)		RPD depth (cm)		OSI	
		06/17/97	11/19/99	06/17/97	11/19/99	06/17/97	11/19/99	06/17/97	11/19/99	06/17/97	11/19/99	06/17/97	11/19/99
B1	b	SA.F		ST_I		3 to 2		4.78		4.66		7	
B2	b	UN.SS	UN.SS	ST_II	ST_I_TO_II	4 to 3	4 to 3	6.13	6.61	4.92	1.94	9	5
B3	a	UN.SS		ST_I		3 to 2		4.64		4.52		7	
B4	a	UN.SS		ST_I		4 to 3		5.2		5.22		7	
B5	a	UN.SS		ST_II		4 to 3		5.22		5.07		9	
B6	b	SA.F	UN.SS	ST_I	ST_I	3 to 2	4 to 3	3.97	6.66	4.09	2.03	7	4
B7	c	UN.SS		ST_II		4 to 3		8.21		5.75		9	
B8	a	UN.SS		ST_II		4 to 3		7.57		5.78		9	
B9	b	UN.SS		ST_I_TO_II		4 to 3		7.01		6.02		8	
B10	b	UN.SS		ST_II		4 to 3		7.23		4.13		9	
B11	c	UN.SS	UN.SS	ST_II	ST_I_ON_III	4 to 3	4 to 3	6.79	7.87	4.44	3.12	9	10
B12	a	UN.SS		ST_I		4 to 3		3.97		4.21		7	
B13	c	SA.F		ST_I		4 to 3		4.53		4.45		7	
B14	b	SA.F		ST_I		3 to 2		3.55		3.32		6	
B15	a	UN.SS	UN.SS	ST_I	ST_I_ON_III	4 to 3	4 to 3	1.79	3.47	1.98	3.07	4	10
B16	b	UN.SS		ST_I		4 to 3		6.64		3.44		6	
B17	c	UN.SS		ST_II		4 to 3		7.67		4.64		9	
B18	b	UN.SS	UN.SS	ST_III	ST_I	4 to 3	4 to 3	7.18	3.47	4.94	1.49	11	3
B19	B		UN.SS		ST_I		4 to 3		4.37		3.43		6
B20	C		UN.SS		ST_I_ON_III		4 to 3		5.16		2.74		9
B21	C		SA.F		ST_I		4 to 3		3.58		3.36		6
B22	A		UN.SS		ST_I_TO_II		4 to 3		4.16		4.06		8
B23	B		UN.SS		ST_I		4 to 3		4.92		3.87		7
B24	B		SA.F		ST_I		4 to 3		3.87		3.87		7
B25	C		SA.F		ST_I		4 to 3		3.08		3.08		6
B26	B		SA.F		ST_I		4 to 3		2.82		2.86		5
B27	A		UN.SS		ST_I_ON_III		4 to 3		4.42		3.11		10
B28	C		UN.SS		ST_I_TO_II		4 to 3		4.05		1.70		5
Average								5.72	4.57	4.52	2.92	8	7
Std Deviation								1.79	1.45	1.00	0.80	2	2
Minimum								1.79	2.82	1.98	1.49	4	3
Maximum								8.21	7.87	6.02	4.06	11	10

Table 7. Comparison of 1997 versus 1999 REMOTS results (all stations at Site 69b).

Station	Rep.	Habitat type		Successional stage		Grain size major mode		Prism penetration (cm)		RPD depth (cm)		OSI	
		06/17/97	11/19/99	06/17/97	11/19/99	06/17/97	11/19/99	06/17/97	11/19/99	06/17/97	11/19/99	06/17/97	11/19/99
A1	a	UN.SS		ST_I		4 to 3		3.86		3.54		6	
A2	a	UN.SS	UN.SS	ST_II	ST_I_ON_III	4 to 3	4 to 3	4.74	8.39	3.11	2.29	8	9
A2	c		HR		INDET		<-1		0.13		NA		NA
A3	c	UN.SS	UN.SS	ST_II	ST_I_ON_III	4 to 3	4 to 3	8.05	10.16	3.39	1.80	8	8
A4	a	UN.SS		ST_II		4 to 3		8.01		4.66		9	
A5	b	UN.SS	UN.SS	ST_II	ST_I_ON_III	4 to 3	4 to 3	6.21	7.03	6.29	3.10	9	10
A6	b	SA.F		ST_I		3 to 2		3.29		3.65		6	
A7	b	UN.SS		ST_I		4 to 3		4		3.7		6	
A8	a	HR		INDET			<-1	0.05		NA		NA	
A9	b	UN.SS		ST_I		4 to 3		8.51		2.89		5	
A10	b	UN.SS	UN.SS	ST_II_ON_III	ST_I	4 to 3	4 to 3	7.06	8.37	3.79	3.25	11	6
A11	b	UN.SS	UN.SS	ST_II	ST_I_TO_II	4 to 3	4 to 3	10.17	10.03	3.71	2.55	8	6
A12	c	SA.F		ST_I		3 to 2		7.24		5.68		7	
A13	c	UN.SS		ST_I		4 to 3		5.69		6.11		7	
A14	b	HR		INDET		3 to 2		0.05		NA		NA	
A14	c	SA.F		ST_I		3 to 2		2.73		2.65		5	
A15	c	SA.F		ST_I		3 to 2		3.49		3.62		6	
A16	c	UN.SS		ST_I_TO_II		4 to 3		6.27		4		8	
A17	c	SA.F		ST_I		3 to 2		3.73		3.58		6	
A18	a	SA.F		ST_I		3 to 2		5.63		5.39		7	
A19	B		SA.F		ST_I		4 to 3		6.29		4.85		7
A20	A		SA.F		ST_I		4 to 3		3.71		3.71		6
A21	A		UN.SS		ST_I_TO_II		4 to 3		4.55		4.55		8
A22	B		UN.SS		ST_I		4 to 3		6.89		4.43		7
A23	B		UN.SS		ST_I_ON_III		4 to 3		6.61		2.69		9
A24	B		UN.SS		ST_I		4 to 3		7.53		4.49		7
A25	B		UN.SS		ST_I_ON_III		4 to 3		8.08		1.00		7
A26	B		UN.SS		ST_I		4 to 3		6.89		1.90		4
A27	B		SA.F		ST_I		4 to 3		4.24		1.51		4
A27	C		UN.SS		ST_I		4 to 3		5.53		1.65		4
A28	C		UN.SS		ST_I_TO_II		4 to 3		5.55		0.93		4
A29	B		UN.SS		ST_I		4 to 3		4.97		2.75		5
A30	B		UN.SS		ST_I_ON_III		4 to 3		4.66		1.77		8
A31	A		UN.SS		ST_I_TO_II		>4		5.24		1.05		4
A31	B		SA.F		ST_I		4 to 3		3.21		2.07		4
A32	A		UN.SS		ST_I		4 to 3		7.42		1.64		4
A32	C		UN.SS		ST_I		4 to 3		10.61		2.85		5
A33	A		UN.SS		ST_I		4 to 3		6.58		1.06		3
A33	B		UN.SS		ST_I_TO_II		4 to 3		6.66		4.26		8
A34	A		UN.SS		ST_I_TO_II		4 to 3		4.39		1.40		4
A35	A		UN.SS		ST_I_TO_II		4 to 3		6.63		1.24		4
Average								5.20	6.31	4.10	2.49	7	6
Std Deviation								2.72	2.28	1.11	1.25	2	2
Minimum								0.05	0.13	2.65	0.93	5	3
Maximum								10.17	10.61	6.29	4.85	11	10

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FIGURES

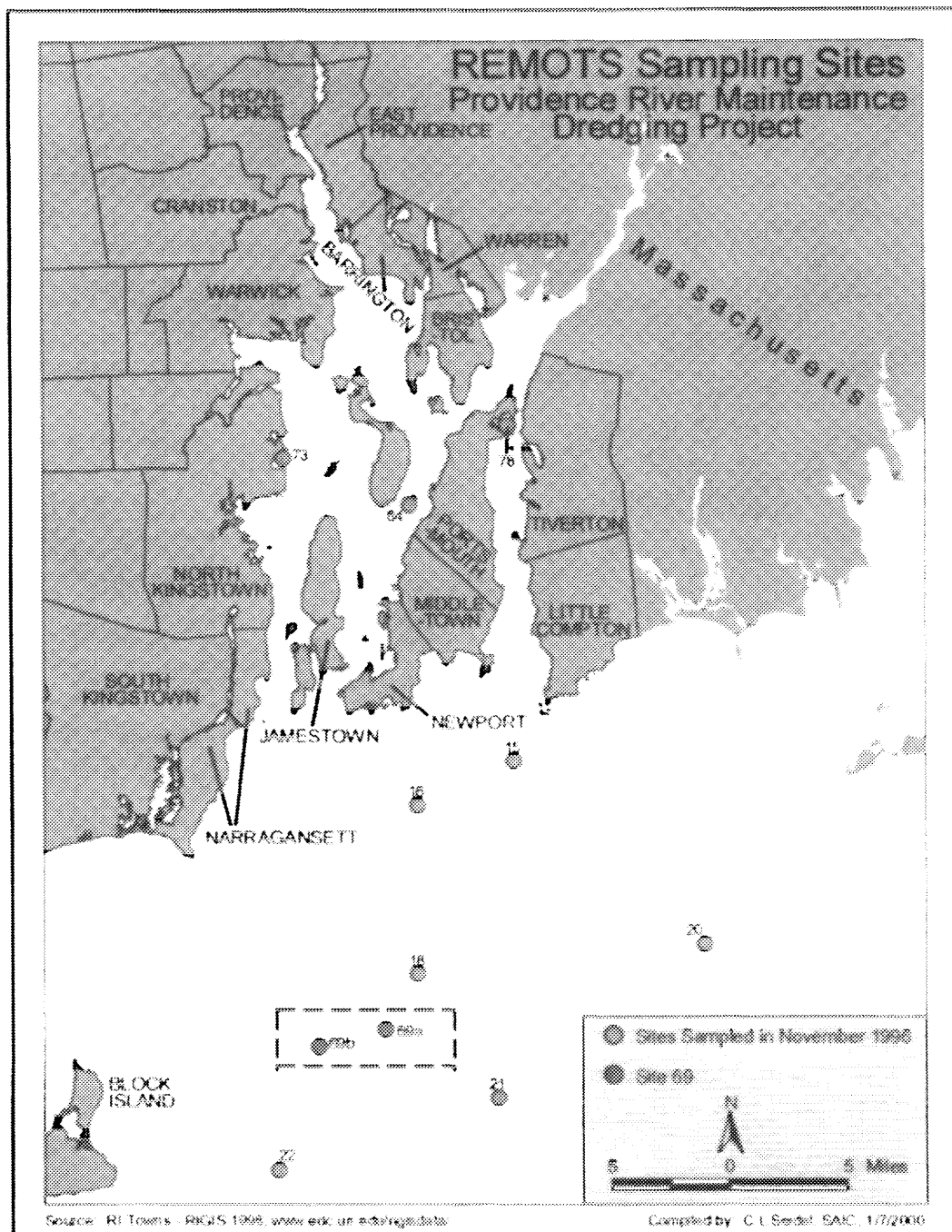


Figure 1. Map showing the location of Sites 69a and 69b in relation to sites surveyed in November 1996. (Note: some of the sites surveyed in November 1996 are no longer being considered as potential disposal sites.)

41° 16.5' N

**Previously Sampled Stations at Sites 69a and 69b
with respect to Original and Revised Site Boundaries**

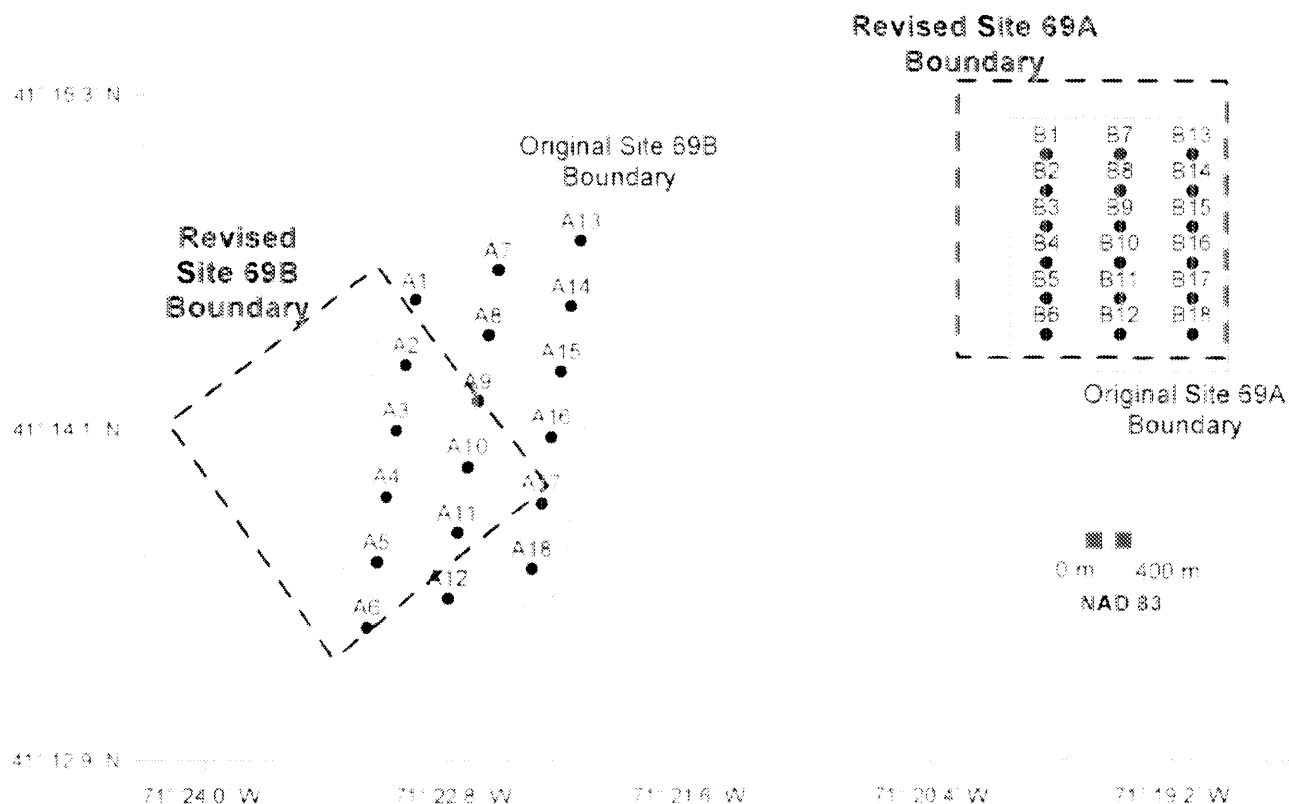


Figure 2. Map showing the REMOTS® sampling stations used in the previous (June 1997) survey of Sites 69a and 69b, in relation to the original and revised site boundaries.

Site 69a and 69b Stations Sampled on 19 November 1999

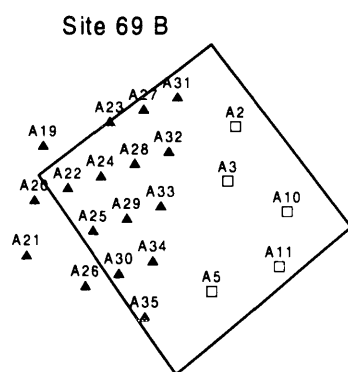
41° 16.5' N

▲ New Stations
□ Repeated Previous Sampling Stations

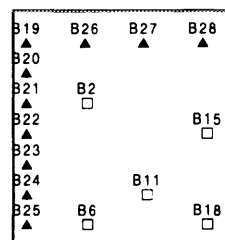
41° 15.3' N

41° 14.1' N

41° 12.9' N



Site 69 A



0 m 400 m

71° 24.0' W 71° 22.8' W 71° 21.6' W 71° 20.4' W 71° 19.2' W

Figure 3. Map showing the location of REMOTS® stations visited in the November 1999 survey of Sites 69a and 69b.

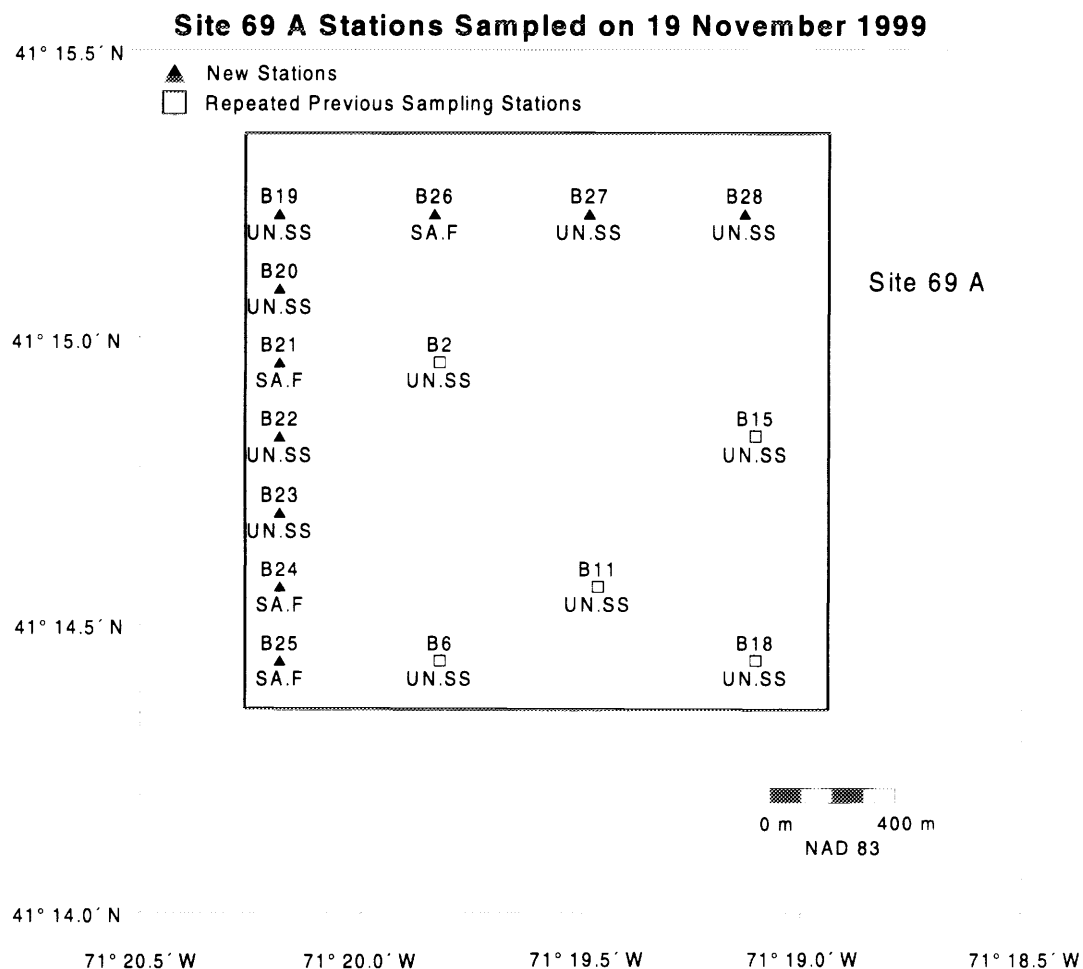


Figure 4. Map of habitat types at the Site 69a sampling stations.

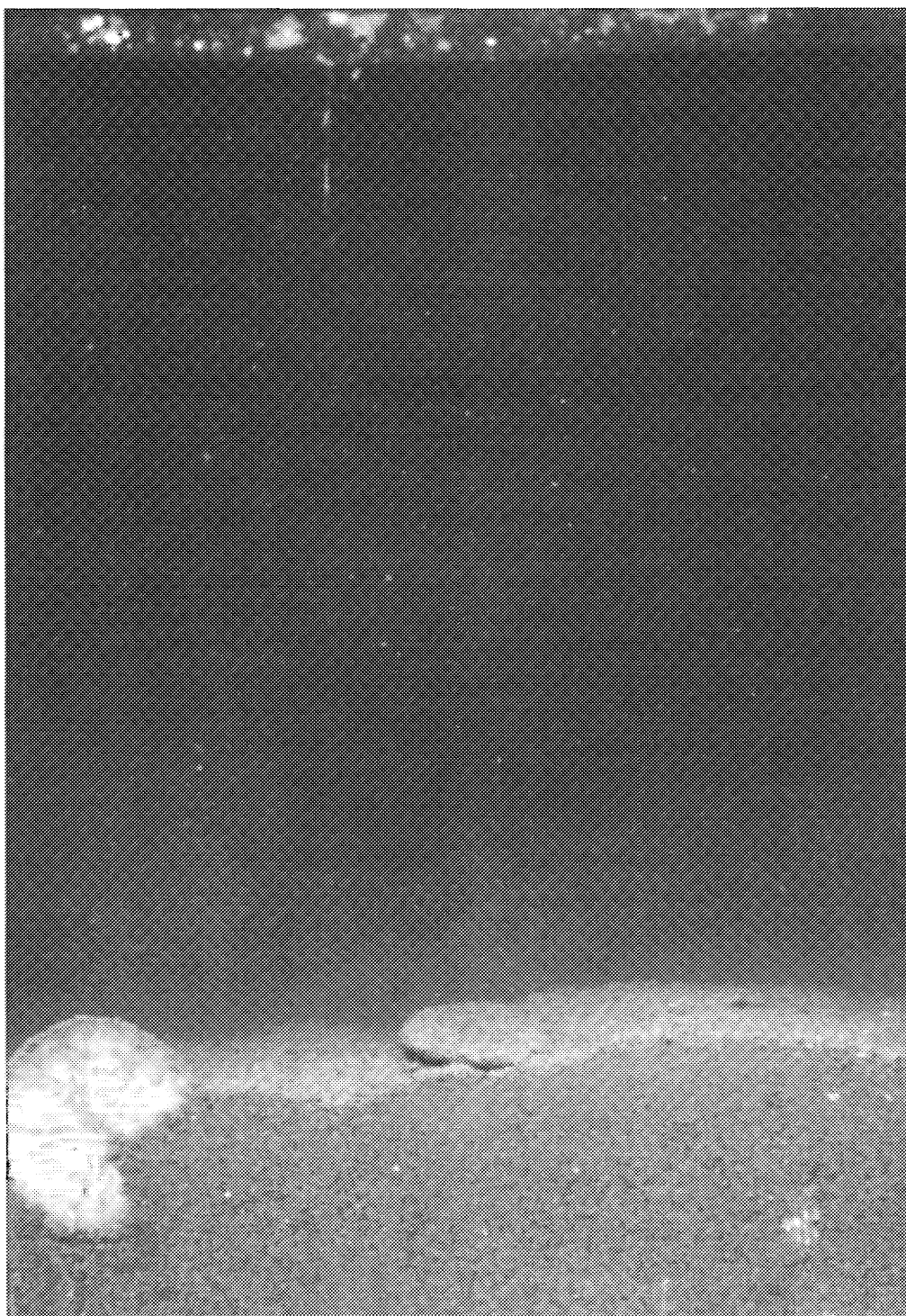


Figure 5. Example of fine sand habitat (SA.F) , Station B24 at Site 69a. A partially covered sand dollar is visible on the sediment surface in the far field and another is wedged against the REMOTS[®] camera faceplate. This image was given a Stage I successional designation due to the presence of numerous small, tubicolous polychaetes at the sediment surface. Scale = actual width of image is 15 cm.

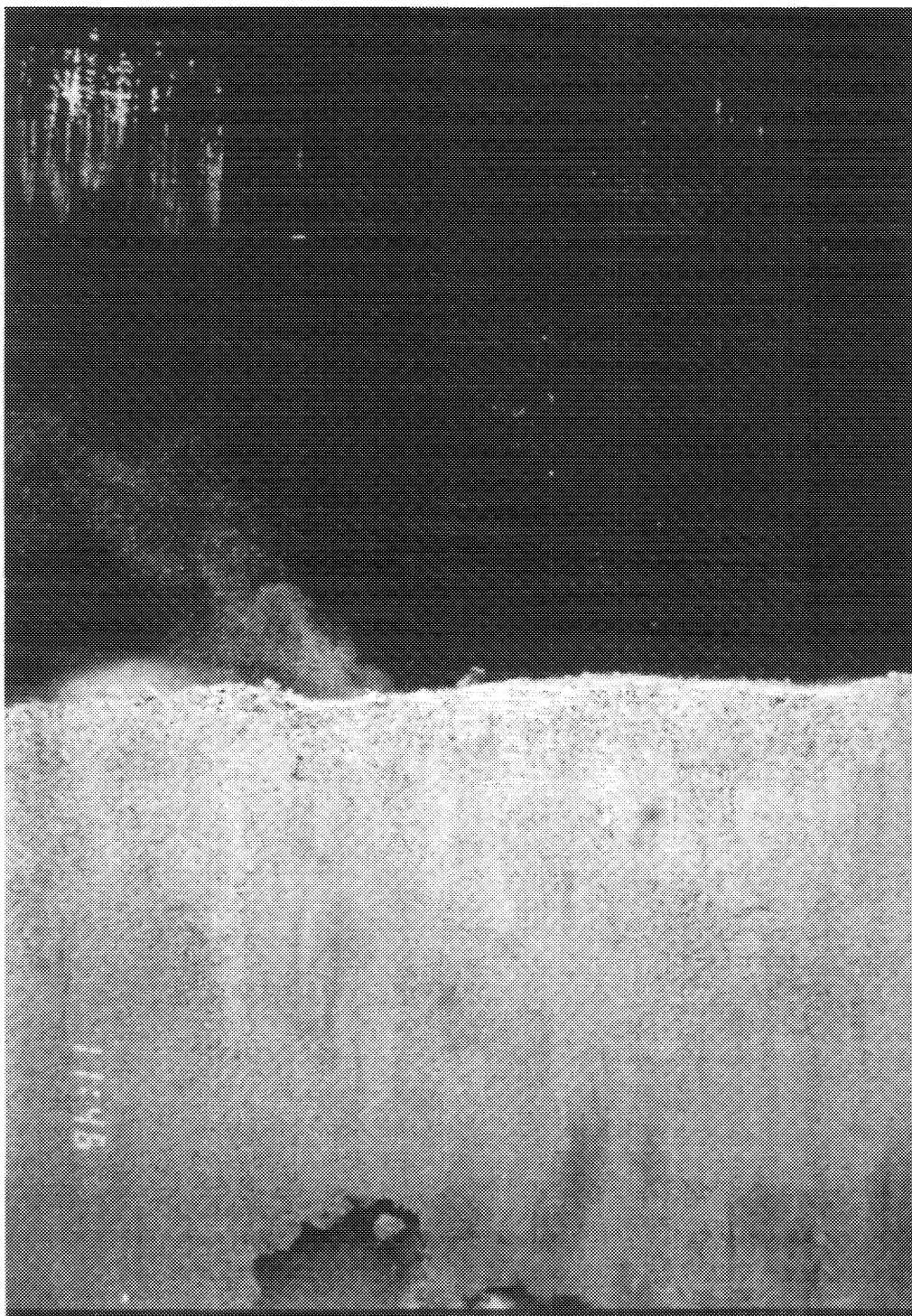


Figure 6. Example of unconsolidated soft bottom, fine sand/silt habitat (UN.SS) at Site 69b, station A3. The image shows unconsolidated, very fine sand with a significant silt-clay fraction. A few small Stage I polychaete tubes are visible at the sediment surface and a Stage III feeding void is visible at the bottom of the image, resulting in a Stage I on III successional designation. Scale = actual width of image is 15 cm.

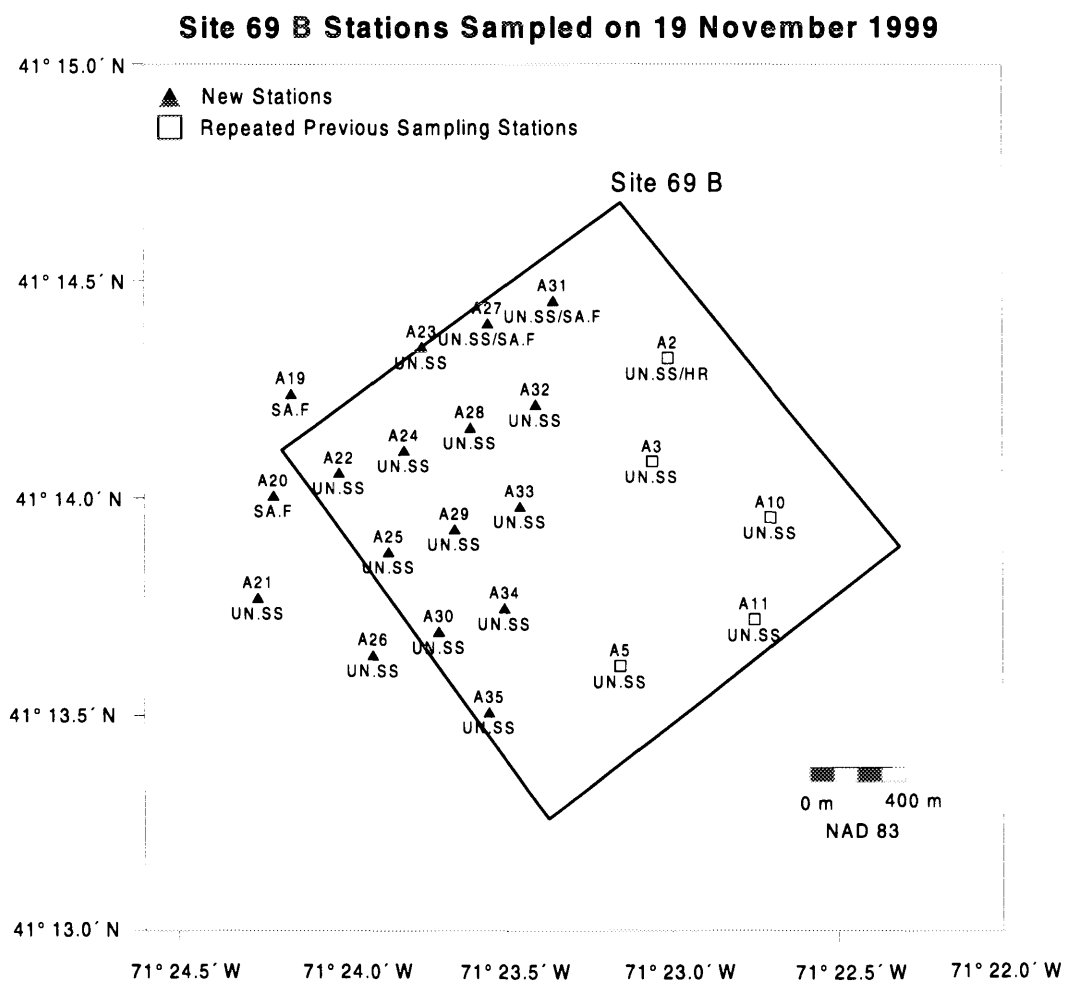


Figure 7. Map of habitat types at the Site 69b sampling stations.

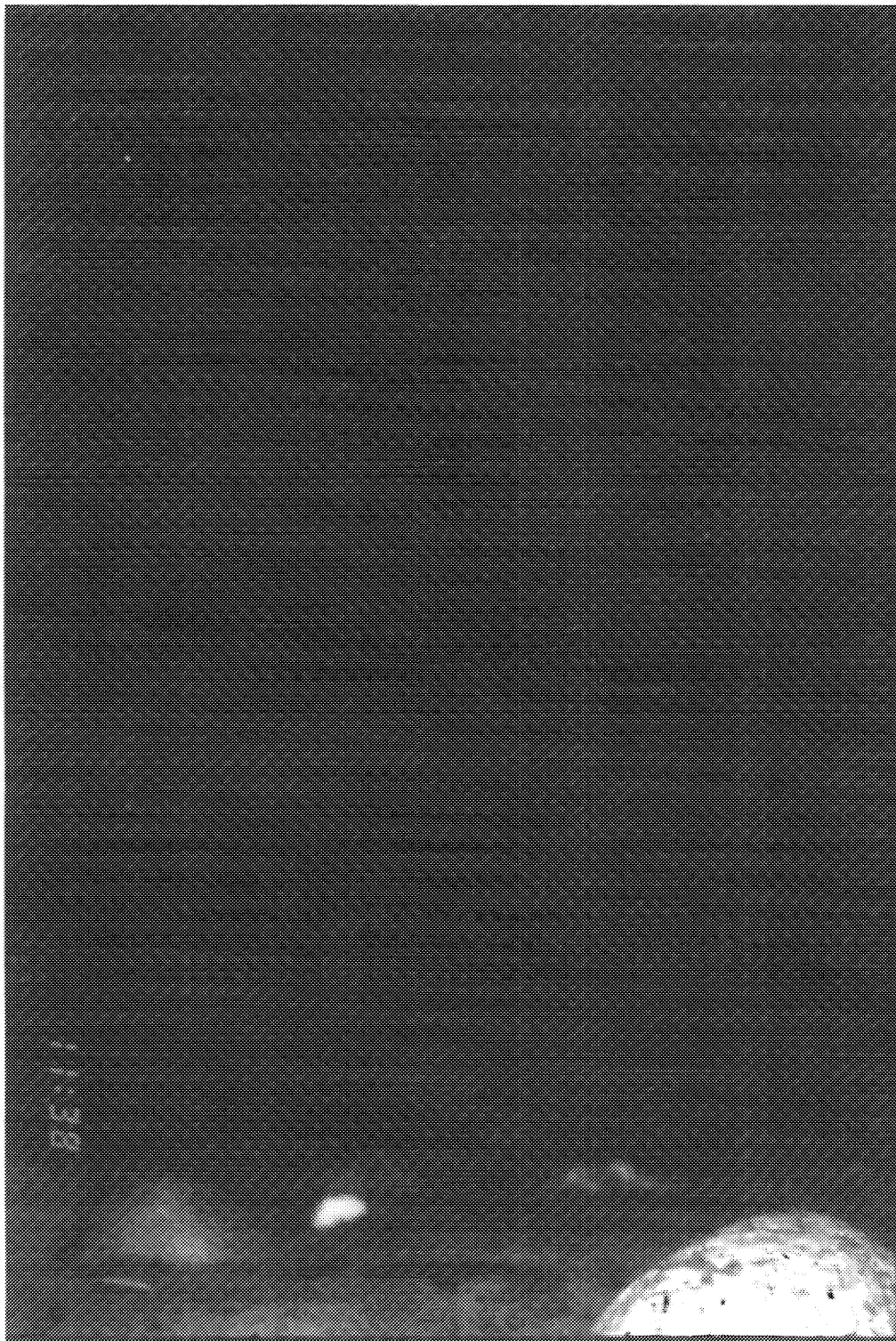


Figure 8. Example of hard rock/gravel habitat (HR), Station A2 at Site 69b. Scale = actual width of image is 15 cm.

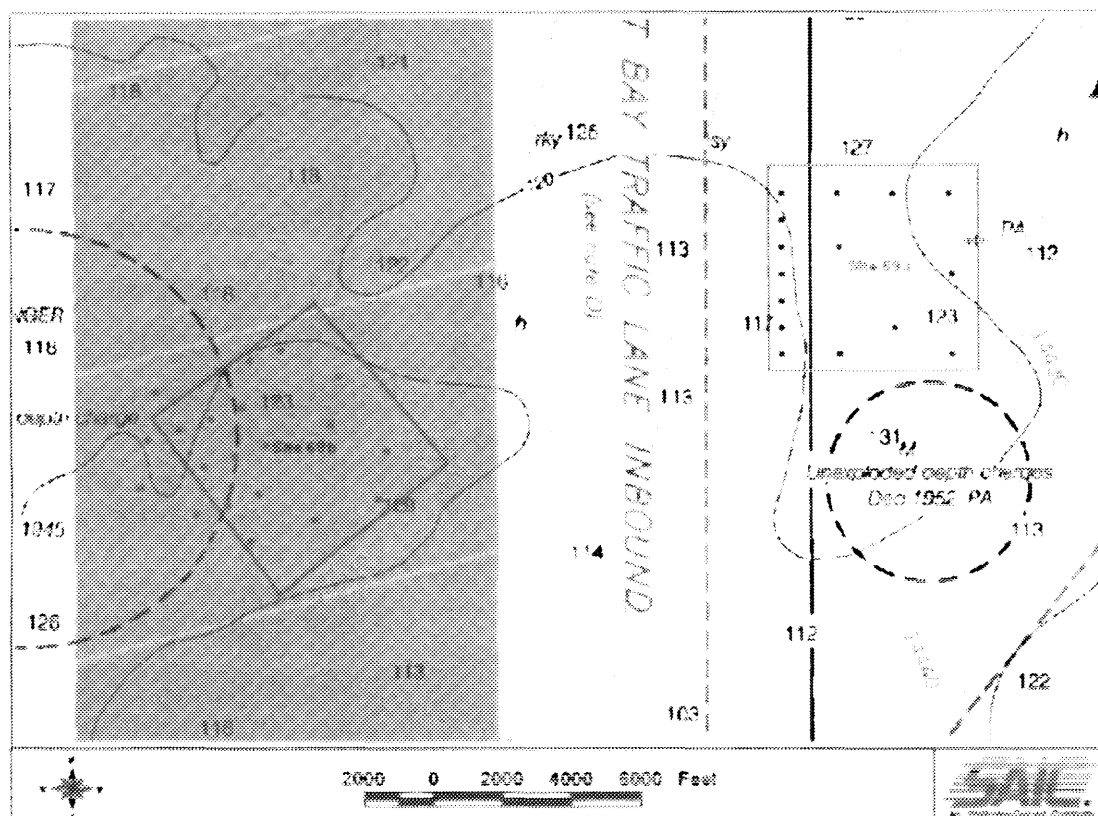


Figure 9. Site 69 boundaries and station locations in relation to depth contours (in feet) from NOAA Chart 13218.

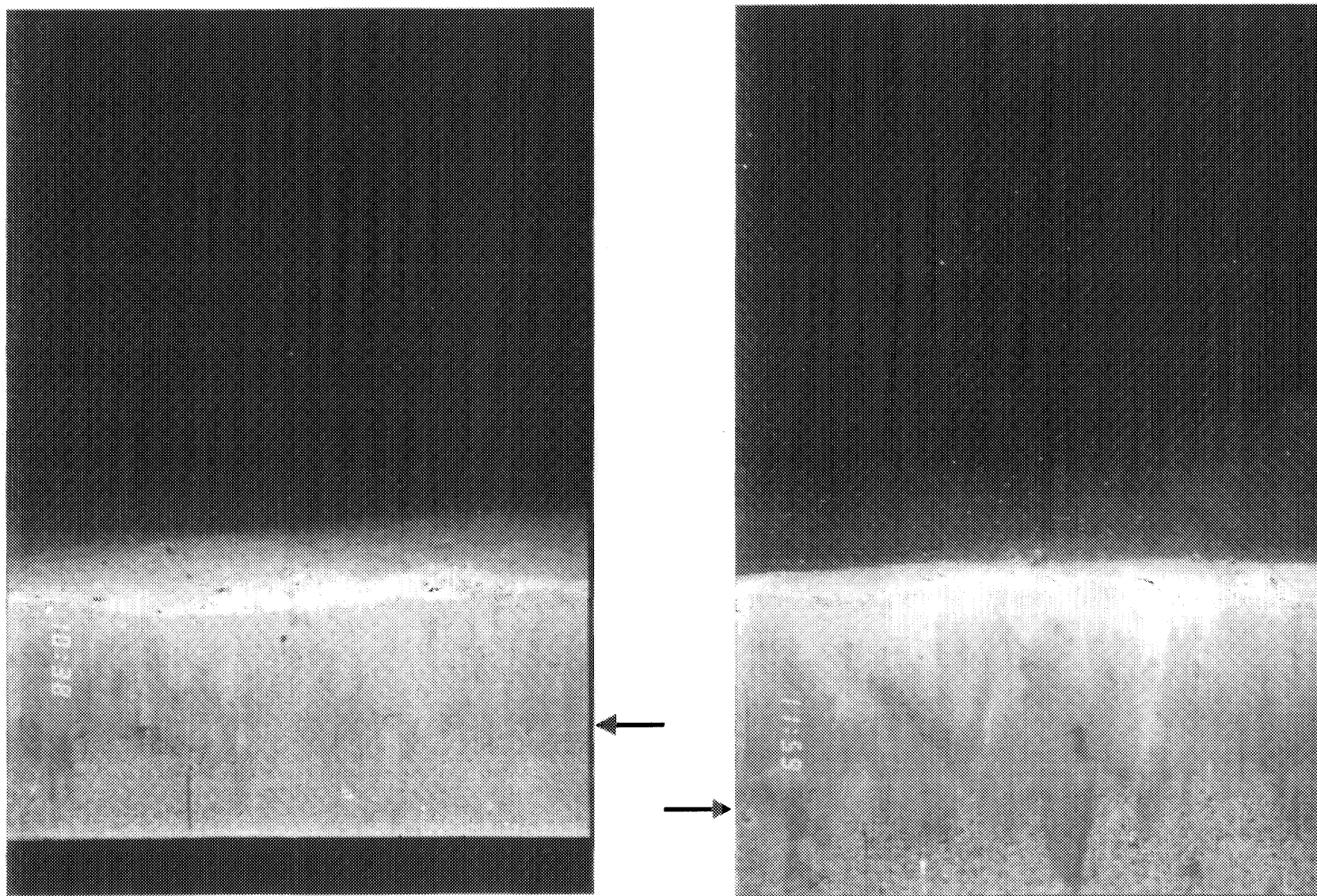


Figure 10. REMOTS® images from Site 69b, Stations (A28 (left) and A33 (right). Both images show a relatively thin surface layer of fine-grained sediment (silt-clay) overlying fine sand at depth. The point of contact between the two layers is marked with an arrow in each image. Scale actual width of each image is 15 cm.

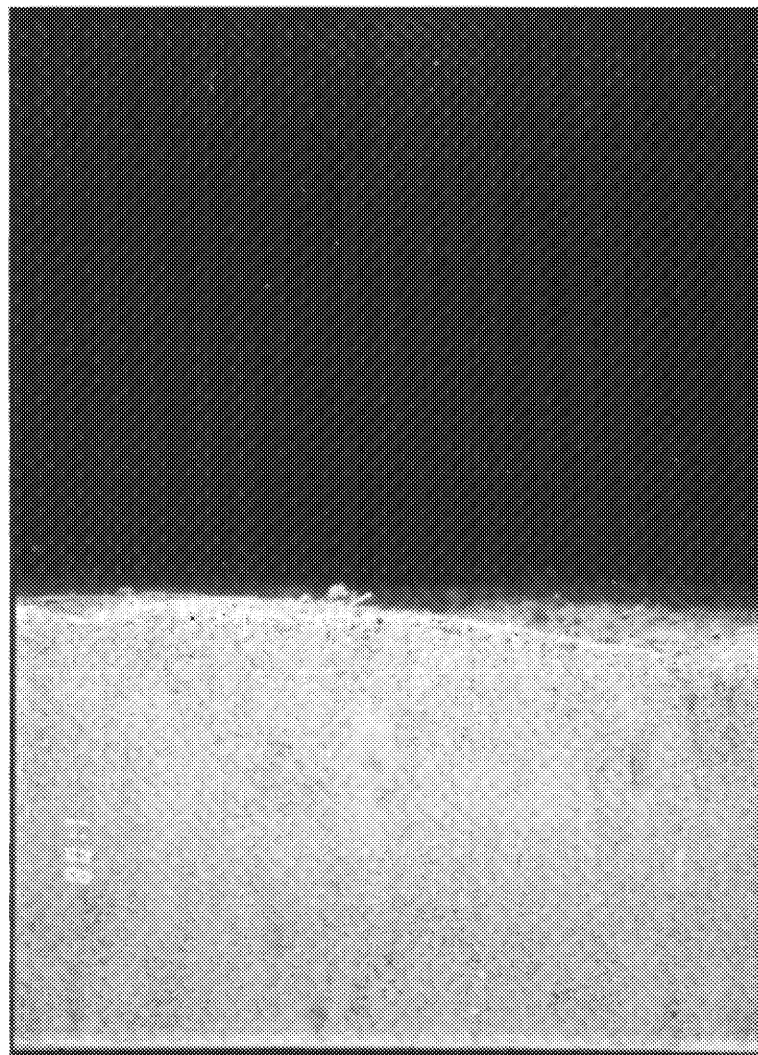
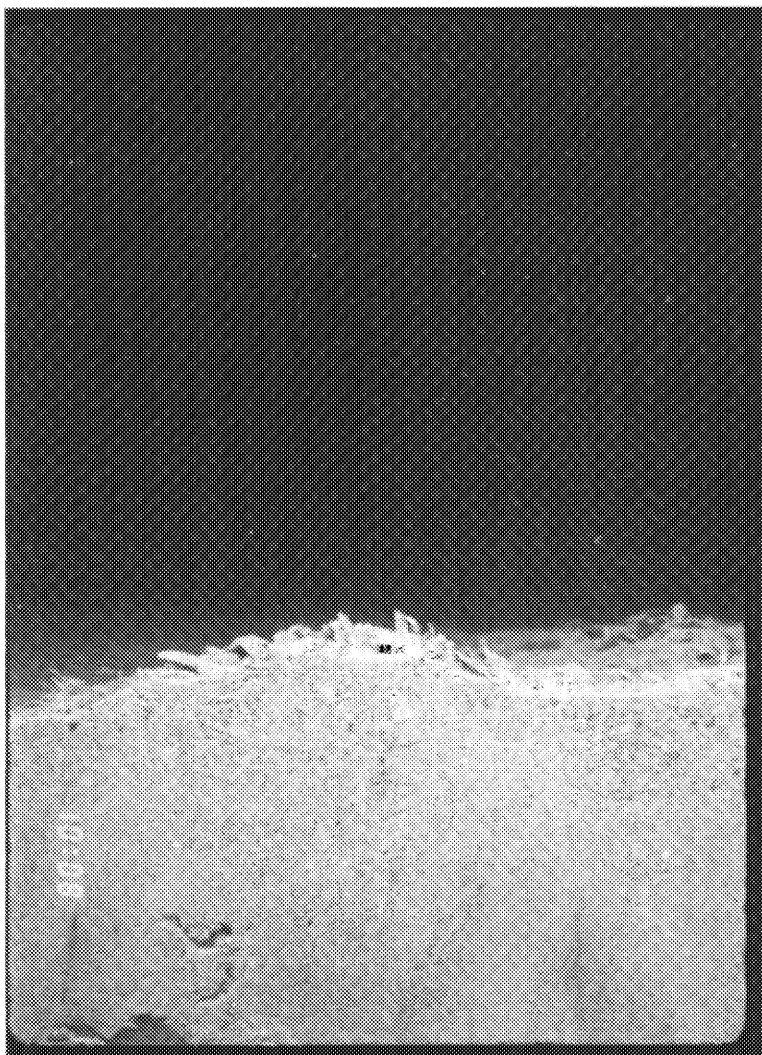


Figure 11. REMOTS® images from Site 69b, Station A10, acquired in June 1997 (left) and November 1999(right). In the 1997 image (left), numerous flat tubes of the amphipod *Ampelisca sp.* are visible at the sediment surface and a feeding void occurs at depth, resulting in a Stage II or III successional designation. In contrast, only a few Stage I polychaete tubes are visible at the sediment surface in the image from the November 1999 survey (right). Scale = actual width of each image is 5 cm.

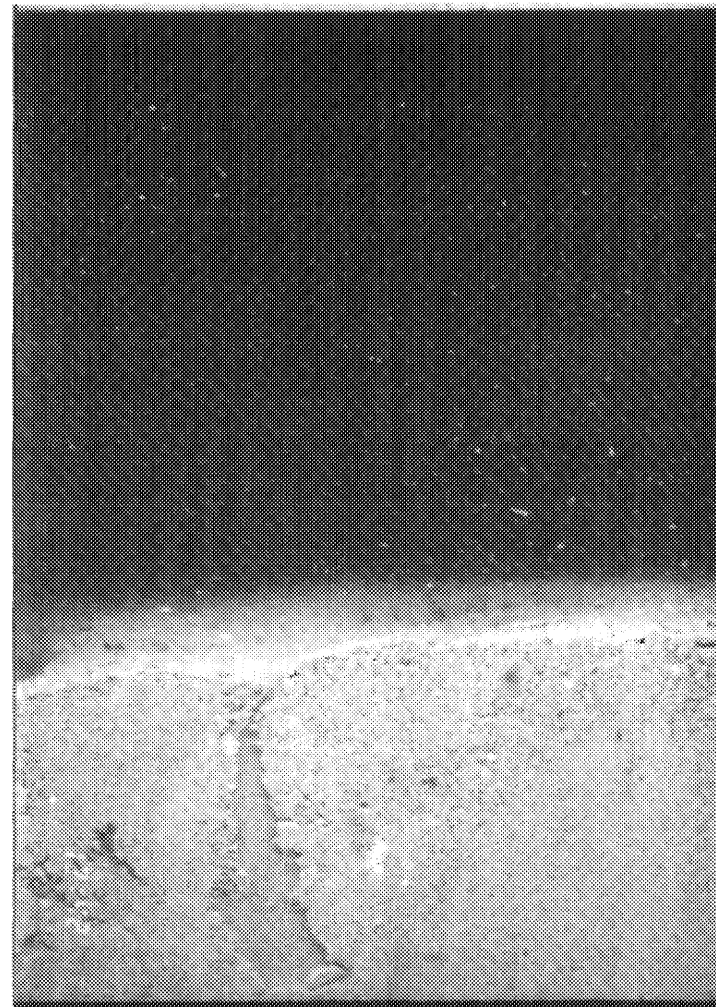
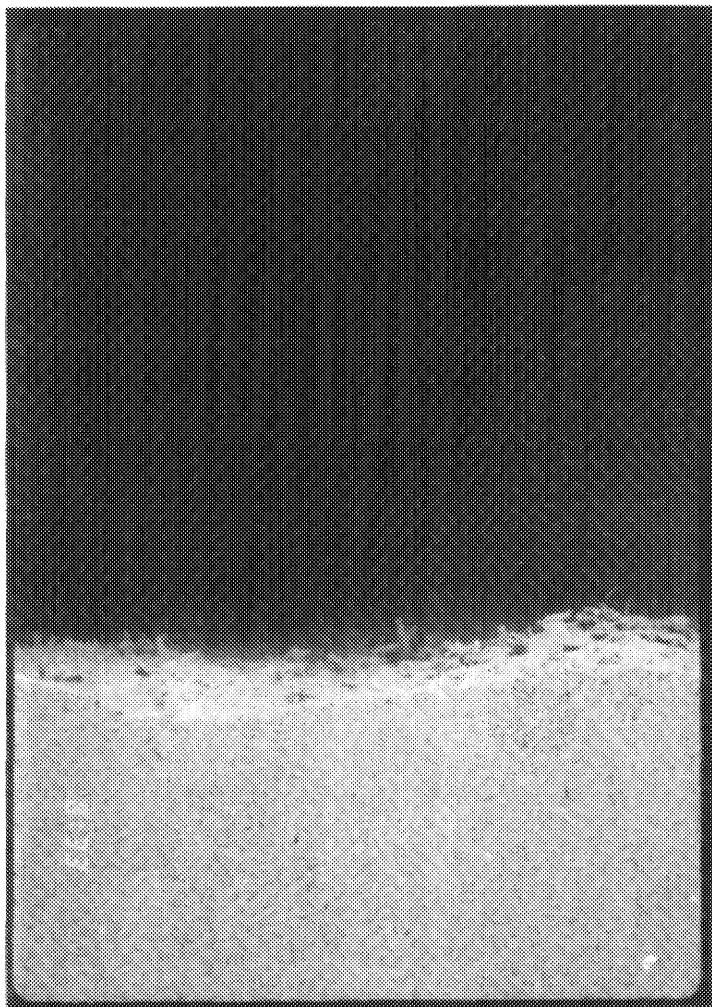


Figure 12. REMOTS® images from Site 69b, Station A5, acquired in June 1997 (left) and November 1999 (right). In the 1997 image (left), there is a relatively dense assemblage of amphipod and polychaete tubes at the sediment surface, resulting in a Stage II successional designation. The image from November 1999 (right shows only a few Stage I polychaete tubes at the sediment surface, a vertical burrow opening extending down through the sediment, and few feeding voids at depth on the left-hand side. This image has a Stage I on III successional designation. Scale = actual width of each image is 15 cm.

Site 69a

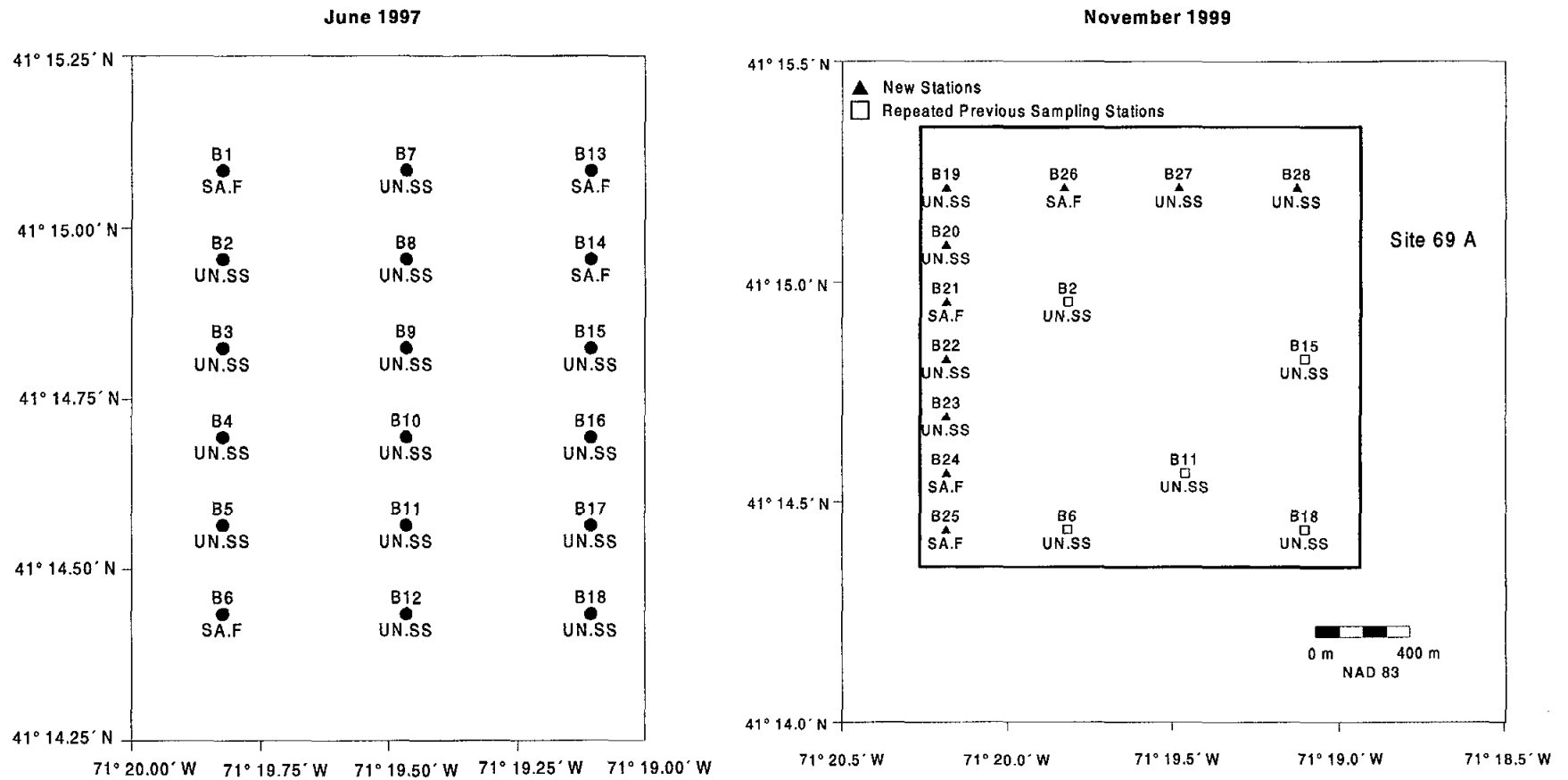


Figure 13. Maps of habitat types at Site 69a sampling stations in June 1997 (left) and November 1999 (right).

Site 69b

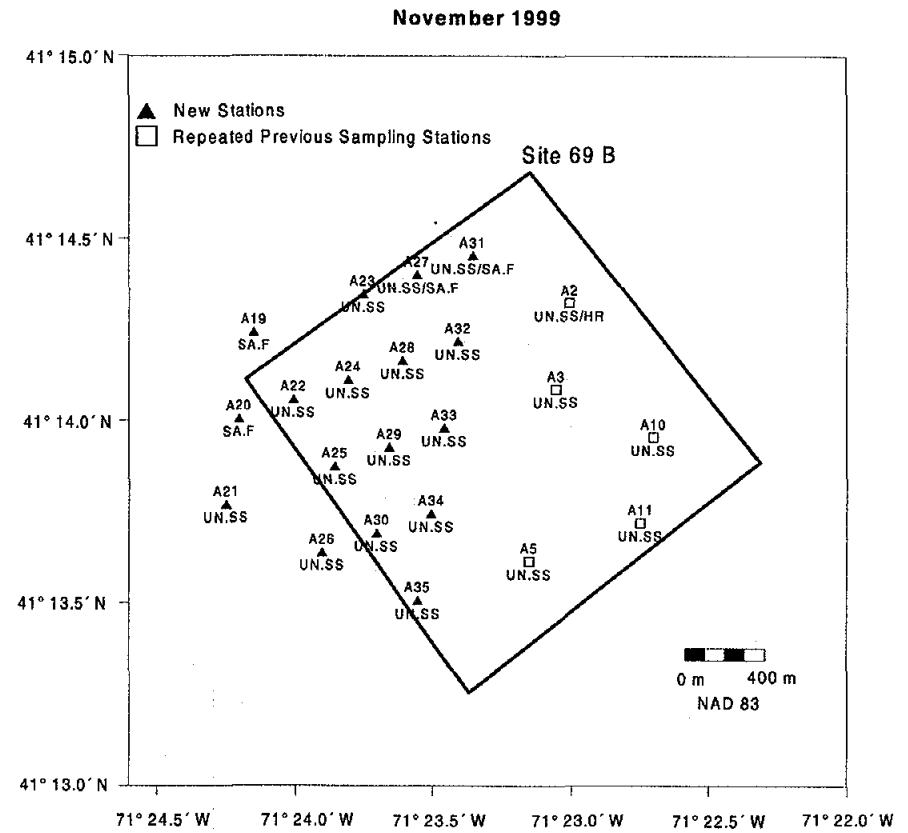
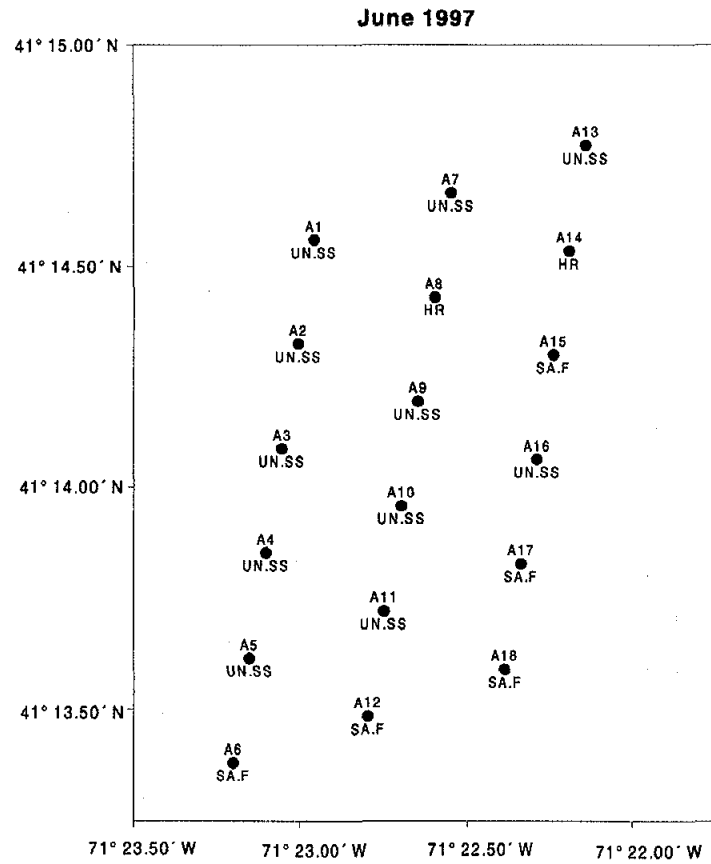


Figure 14. Maps of habitat types at Site 69b sampling stations in June 1997 (left) and November 1999 (right).

APPENDIX A

Methods for REMOTS[®] Image Acquisition and Interpretation

METHODS FOR REMOTS® IMAGE ACQUISITION AND INTERPRETATION

INTRODUCTION

Sediment-profile imaging is a benthic sampling technique in which a specialized camera is used to obtain vertical cross-section photographs (profiles) of the upper 15 to 20 cm of the seafloor. This is a reconnaissance survey technique used for rapid collection, interpretation and mapping of data on physical and biological seafloor characteristics; it has been employed in estuarine, coastal and deep-sea environments worldwide for almost 20 years. Measurements obtained from sediment-profile images are used to characterize sediment types, evaluate benthic habitat quality, map disturbance gradients, and follow ecosystem recovery after disturbance abatement. This technique was first introduced under the name REMOTS® (REmote Ecological Monitoring Of The Seafloor), a registered trademark of Science Applications International Corporation (SAIC). REMOTS® is a formal and standardized technique for sediment-profile imaging and analysis (Rhoads and Germano 1982 1986). In generic terms, this sampling technique is called sediment-profile imaging (SPI) or sediment vertical profile imaging (SVPI).

Typical parameters measured from sediment-profile images include sediment grain size, depth of the apparent redox potential discontinuity (a measure of oxygen penetration into the bottom), thickness of dredged material or other depositional layers, benthic infaunal successional stage, and presence/absence of methane gas bubbles. A summary metric called the Organism-Sediment Index (OSI) is calculated for each image and is used to numerically score benthic habitat quality. The OSI defines quality of benthic habitats by evaluating images for depth of the apparent RPD, successional stage of macrofauna, the presence of methane gas voids in the sediment (an indication of high rates of organic loading), and the presence of reduced (anaerobic) sediment at the sediment-water interface. The OSI ranges from -10, poorest quality habitats, to +11, highest quality habitats. Detailed descriptions of the methods employed by SAIC for the acquisition and interpretation (analysis) of REMOTS® sediment-profile images follow. Additional details on the theory of sediment-profile image interpretation can be found in Rhoads and Germano (1982 and 1986). The basis of successional dynamics is described in Rhoads et al. 1978.

REMOTS® IMAGE ACQUISITION

The Model 3731 sediment-profile camera utilized by SAIC is manufactured by Benthos, Inc. of North Falmouth, MA (Figure 1-1). The camera is designed to obtain *in situ* profile images of the top 20 cm of sediment. Functioning like an inverted periscope, the camera consists of a wedge-shaped prism with a front faceplate and a back mirror mounted at a 45-degree angle to reflect the profile of the sediment-water interface facing the camera. The prism is filled with distilled water, the assembly contains an internal strobe used to illuminate the images, and a 35-mm camera is mounted horizontally on top of the prism. The prism assembly is moved up and down into the sediments by producing tension or slack on the winch wire. Tension on the wire keeps the prism in the up position, out of the sediments.

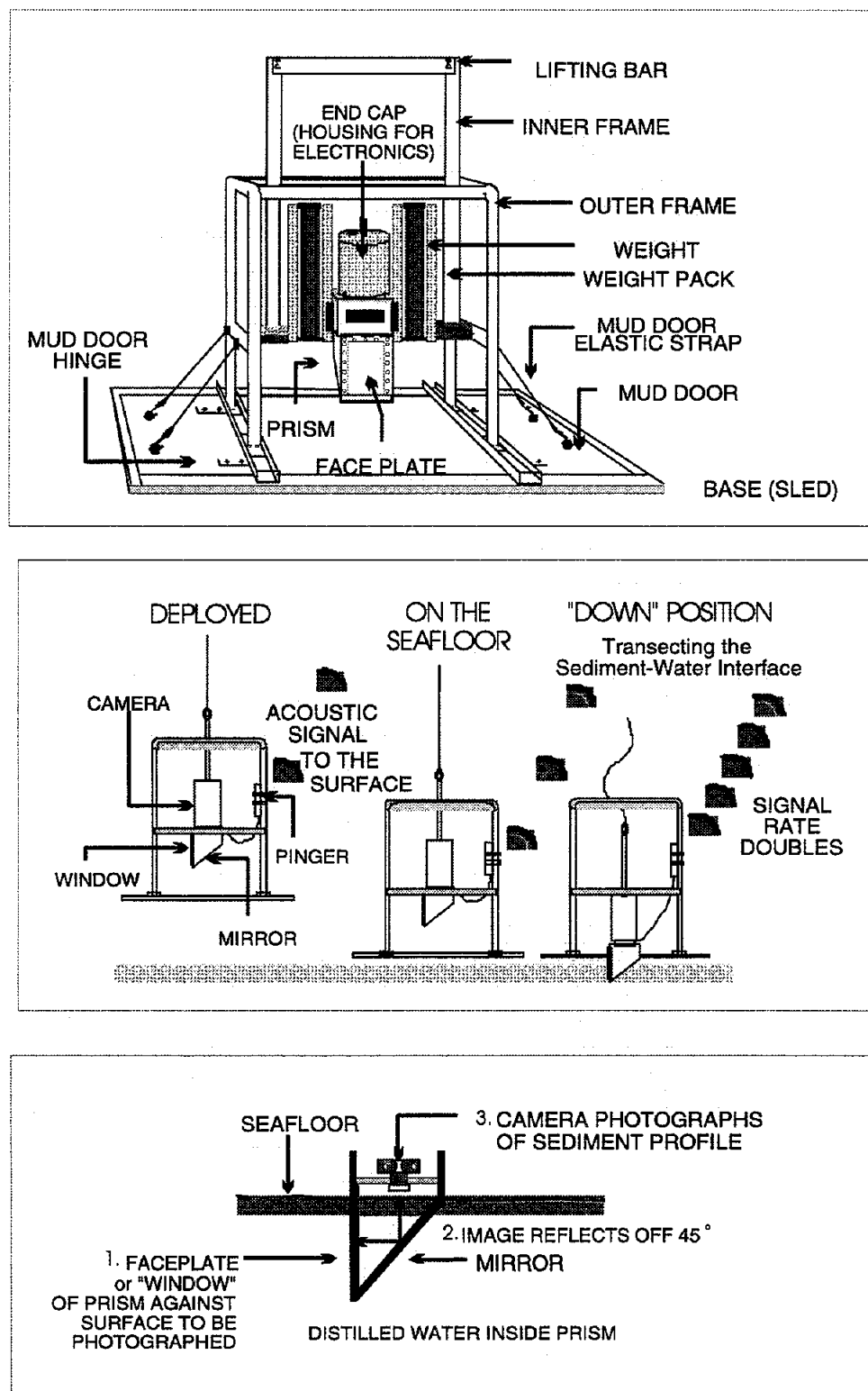


Figure 1-1. Schematic diagram of Benthos, Inc. Model 3731 REMOTS® sediment-profile camera and sequence of operation on deployment.

The camera frame is lowered to the seafloor at a rate of about 1 m/sec (Figure 1-1). When the frame settles onto the bottom, slack on the winch wire allows the prism to penetrate the seafloor vertically. A passive hydraulic piston ensures that the prism enters the bottom slowly (approximately 6 cm/sec) and does not disturb the sediment-water interface. As the prism starts to penetrate the seafloor, a trigger activates a 13-second time delay on the shutter release to allow maximum penetration before a photo is taken. A Benthos Model 2216 Deep Sea Pinger is attached to the camera and outputs a constant 12 kHz signal of one ping per second; upon discharge of the camera strobe, the ping rate doubles for 10 seconds. Monitoring the signal output on deck provides confirmation that a successful image was obtained. Because the sediment photographed is directly against the faceplate, turbidity of the ambient seawater does not affect image quality. When the camera is raised, a wiper blade cleans off the faceplate, the film is advanced by a motor drive, the strobe is recharged, and the camera can be lowered for another image.

REMOTS® IMAGE ANALYSIS

The sediment-profile images were analyzed with SAIC's full-color, image analysis system. This is a PC-based system integrated with a Javelin CCTV video camera and frame grabber. Color slides are digitally recorded as color images on computer disk. The image analysis software is a menu-driven program that incorporates user commands via keyboard and mouse. The system displays each color image (35-mm slide) on the CRT while measurements of physical and biological parameters are obtained. Proprietary SAIC software allows the measurement and storage of data on up to 21 different variables for each sediment-profile image obtained. Automatic disk storage of all measured parameters allows data from any variables of interest to be compiled, sorted, displayed graphically, contoured, or compared statistically. All measurements were printed out on data sheets for a quality control check by an SAIC Senior Scientist before being approved for final data synthesis, statistical analysis, and interpretation. A summary of the major categories of measurement data is presented below.

Sediment Type Determination

The sediment grain size major mode and range are estimated visually from the photographs by overlaying a grain size comparator which is at the same scale. This comparator was prepared by photographing a series of Udden-Wentworth size classes (equal to or less than coarse silt up to granule and larger sizes) through the REMOTS® camera. Seven grain size classes are on this comparator: $>4 \phi$ (ϕ), $4-3 \phi$, $3-2 \phi$, $2-1 \phi$, $1-0 \phi$, $0-(-1 \phi)$, and $<-1 \phi$. The lower limit of optical resolution of the photographic system is about 62 microns (4ϕ), allowing recognition of grain sizes equal to or greater than coarse silt. The accuracy of this method has been documented by comparing REMOTS® estimates with grain size statistics determined from laboratory sieve analyses.

The major modal grain size that is assigned to an image is the dominant grain size as estimated by area within the imaged sediment column. In those images that show layering of sand and mud, the dominant major mode assigned to a replicate therefore depends on how much area of the photograph is represented by sand versus mud. These textural assignments may or may not correspond to traditional sieve analyses depending on how closely the vertical sampling intervals are matched between the grab or core sample and the depth of the imaged sediment.

Surface Boundary Roughness

Small-scale surface boundary roughness is measured from an image with the computer image analysis system. This vertical measurement is from the highest point at the sediment-water interface to the lowest point. This measurement of vertical relief is made within a horizontal distance of 15 cm (the total width of the optical window). Because the optical window is 20 cm high, the greatest possible roughness value

is 20 cm. The source of the roughness is described if known. In most cases this is either biogenic (mounds and depressions formed by bioturbation or foraging activity) or relief formed by physical processes (ripples, scour depressions, rip-ups, mud clasts, etc.).

Optical Prism Penetration Depth

The optical prism penetrates the bottom under a static driving force imparted by the weight of the descending optical prism, camera housing, supporting mechanism, and weight packs. The penetration depth into the bottom depends on the force exerted by the optical prism and the bearing strength of the sediment. If the weight of the camera prism is held constant, the change in penetration depth over a surveyed site will reflect changes in geotechnical properties of the bottom. In this sense, the camera prism acts as a static-load penetrometer. The depth of penetration of the optical prism into the bottom can be a useful parameter, because dredged and capped materials often will have different shear strengths and bearing capacities.

Mud Clasts

When fine-grained, cohesive sediments are disturbed, either by physical bottom scour or faunal activity (e.g., decapod foraging), intact clumps of sediment are often scattered about the seafloor. These mud clasts can be seen at the sediment-water interface in REMOTS[®] images. During analysis, the number of clasts is counted, the diameter of a typical clast is measured, and their oxidation state is assessed. Depending on their place of origin and the depth of disturbance of the sediment column, mud clasts can be reduced or oxidized. Also, once at the sediment-water interface, these sediment clumps are subject to bottom-water oxygen levels and bottom currents. Based on laboratory microcosm observations of reduced sediments placed within an aerobic environment, oxidation of reduced surface layers by diffusion alone is quite rapid, occurring within 6-12 hours (Germano 1983). Consequently, the detection of reduced mud clasts in an obviously aerobic setting suggests a recent origin. The size and shape of mud clasts, e.g., angular versus rounded, are also considered. Mud clasts may be moved about and broken by bottom currents and/or animals (macro- or meiofauna; Germano 1983). Over time, large angular clasts become small and rounded. Overall, the abundance, distribution, oxidation state, and angularity of mud clasts are used to make inferences about the recent pattern of seafloor disturbance in an area.

Measurement of Dredged Material Layers, Cap Layers or other Depositional Layers

Distinct sedimentary horizons are clearly distinguishable in sediment profile images. Typically, depositional layers at the sediment surface or sedimentary horizons at depth are distinguished on the basis of their unique texture and/or color. Depositional layers may be the result of natural processes (e.g., sediment erosion, transport and deposition), or anthropogenic activities like dredged material disposal or capping. The recognition of dredged material from REMOTS[®] images is usually based on the presence of anomalous sedimentary materials within an area of ambient sediment. The ability to distinguish between ambient sediment and dredged or cap material demands that the survey extend well beyond the margins of a disposal site so that an accurate characterization of the ambient bottom is obtained. The distributional anomalies may be manifested in topographic roughness, differences in grain size, sorting, shell content, optical reflectance, fabric, or sediment compaction (i.e., camera prism penetration depth). Second-order anomalies may also provide information about the effects of dredged material on the benthos and benthic processes such as bioturbation (see following sections).

Apparent Redox Potential Discontinuity (RPD) Depth

Aerobic near-surface marine sediments typically have higher reflectance values relative to underlying anoxic sediments. Sand also has higher optical reflectance than mud. These differences in optical reflectance are readily apparent in REMOTS[®] images; the oxidized surface sediment contains particles coated with ferric hydroxide (an olive color when associated with particles), while reduced and muddy sediments below this oxygenated layer are darker, generally grey to black. The boundary between the colored ferric hydroxide surface sediment and underlying grey to black sediment is called the apparent redox potential discontinuity (RPD).

The depth of the apparent RPD in the sediment column is an important time-integrator of dissolved oxygen conditions within sediment pore waters. In the absence of bioturbating organisms, this high reflectance layer (in muds) will typically reach a thickness of 2 mm (Rhoads 1974). This depth is related to the supply rate of molecular oxygen by diffusion into the bottom and the consumption of that oxygen by the sediment and associated microflora. In sediments that have very high sediment-oxygen demand, the sediment may lack a high reflectance layer even when the overlying water column is aerobic.

In the presence of bioturbating macrofauna, the thickness of the high reflectance layer may be several centimeters. The relationship between the thickness of this high reflectance layer and the presence or absence of free molecular oxygen in the associated pore waters must be made with caution. The boundary (or horizon) which separates the positive Eh region (oxidized) from the underlying negative Eh region (reduced) can only be determined accurately with microelectrodes. For this reason, we describe the optical reflectance boundary, as imaged, as the "apparent" RPD, and it is mapped as a mean value.

The depression of the apparent RPD within the sediment is relatively slow in organic-rich muds (on the order of 200 to 300 micrometers per day); therefore, this parameter has a long time constant (Germano and Rhoads 1984). The rebound in the apparent RPD is also slow (Germano 1983). Measurable changes in the apparent RPD depth using the REMOTS[®] optical technique can be detected over periods of one or two months. This parameter is used effectively to document changes (or gradients) which develop over a seasonal or yearly cycle related to water temperature effects on bioturbation rates, seasonal hypoxia, sediment oxygen demand, and infaunal recruitment. In sediment-profile surveys of ocean disposal sites sampled seasonally or on an annual basis throughout the New England region performed under the DAMOS (Disposal Area Monitoring System) Program for the U.S. Army Corps of Engineers, New England Division, SAIC repeatedly has documented a drastic reduction in apparent RPD depths at disposal sites immediately after dredged material disposal, followed by a progressive postdisposal apparent RPD deepening (barring further physical disturbance). Consequently, time-series RPD measurements can be a critical diagnostic element in monitoring the degree of recolonization in an area by the ambient benthos.

The depth of the mean apparent RPD also can be affected by local erosion. The peaks of disposal mounds commonly are scoured by divergent flow over the mound. This can result in washing away of fines, development of shell or gravel lag deposits, and very thin apparent RPD depths. During storm periods, erosion may completely remove any evidence of the apparent RPD (Fredette et al. 1988).

Another important characteristic of the apparent RPD is the contrast in reflectance values at this boundary. This contrast is related to the interactions among the degree of organic-loading, bioturbational activity in the sediment, and the levels of bottom-water dissolved oxygen in an area. High inputs of labile organic material increase sediment oxygen demand and, subsequently, sulfate reduction rates (and the abundance of sulfide end-products). This results in more highly reduced (lower reflectance) sediments at depth and higher RPD contrasts. In a region of generally low RPD contrasts, images with

high RPD contrasts indicate localized sites of relatively high past inputs of organic-rich material (e.g., organic or phytoplankton detritus, dredged material, sewage sludge, etc.).

Sedimentary Methane

At extreme levels of organic-loading, pore-water sulphate is depleted, and methanogenesis occurs. The process of methanogenesis is detected by the appearance of methane bubbles in the sediment column. These gas-filled voids are readily discernible in REMOTS® images because of their irregular, generally circular aspect and glassy texture (due to the reflection of the strobe off the gas). If present, the number and total areal coverage of all methane pockets are measured.

Infaunal Successional Stage

The mapping of successional stages, as employed in this project, is based on the theory that organism-sediment interactions in fine-grained sediments follow a predictable sequence after a major seafloor perturbation (e.g., passage of a storm, disturbance by bottom trawlers, dredged material deposition, hypoxia). This theory states that primary succession results in "the predictable appearance of macrobenthic invertebrates belonging to specific functional types following a benthic disturbance. These invertebrates interact with sediment in specific ways. Because functional types are the biological units of interest, our definition does not demand a sequential appearance of particular invertebrate species or genera" (Rhoads and Boyer 1982). This theory is formally developed in Rhoads and Germano (1982; 1986) and Rhoads and Boyer (1982).

The term disturbance is used here to define natural processes, such as seafloor erosion, changes in seafloor chemistry, and foraging disturbances which cause major reorganization of the resident benthos; disturbance also includes anthropogenic impacts, such as dredged material or sewage sludge disposal, thermal effluent from power plants, bottom trawling, pollution impacts from industrial discharge, etc. An important aspect of using this successional approach to interpret benthic monitoring results is relating organism-sediment relationships to the dynamical aspects of end-member successional stages (i.e., Stage I, II, or III communities as defined in the following paragraphs). This involves deducing dynamics from structure, a technique pioneered by R. G. Johnson (1972) for marine soft-bottom habitats. The application of this approach to benthic monitoring requires *in situ* measurements of salient structural features of organism-sediment relationships as imaged through REMOTS® technology.

Pioneering assemblages (Stage I) usually consist of dense aggregations of near-surface living, tube-dwelling polychaetes; alternately, opportunistic bivalves may colonize in dense aggregations after a disturbance (Rhoads and Germano 1982, Santos and Simon 1980a). These functional types are usually associated with a shallow redox boundary; bioturbation depths are shallow, particularly in the earliest stages of colonization. In the absence of further disturbance, these early successional assemblages are eventually replaced by infaunal deposit feeders; the start of this "infaunalization" process is designated arbitrarily as Stage II. Typical Stage II species are shallow dwelling bivalves or, as is common in New England waters, tubicolous amphipods. In studies of hypoxia-induced benthic defaunation events in Tampa Bay, Florida, ampeliscid amphipods appeared as the second temporal dominant in two of the four recolonization cycles (Santos and Simon 1980a, 1980b).

Stage III taxa, in turn, represent high-order successional stages typically found in low-disturbance regimes. These invertebrates are infaunal, and many feed at depth in a head-down orientation. The localized feeding activity results in distinctive excavations called feeding voids. Diagnostic features of these feeding structures include a generally semicircular shape with a flat bottom and arched roof, and a distinct granulometric change in the sediment particles overlying the floor of the structure. This

granulometric change is caused by the accumulation of coarse particles that are rejected by the animals feeding selectively on fine-grained material. Other subsurface structures, such as burrows or methane gas bubbles, do not exhibit these characteristics and therefore are quite distinguishable from these distinctive feeding structures. The bioturbational activities of these deposit-feeders are responsible for aerating the sediment and causing the redox horizon to be located several centimeters below the sediment-water interface. In the retrograde transition of Stage III to Stage I, it is sometimes possible to recognize the presence of relic (i.e., collapsed and inactive) feeding voids.

The end-member stages (Stages I and III) are easily recognized in REMOTS[®] images by the presence of dense assemblages of near-surface polychaetes and the presence of subsurface feeding voids, respectively. Both types of assemblages may be present in the same image. Additional information on REMOTS[®] image interpretation can be found in Rhoads and Germano (1982, 1986).

Organism-Sediment Index (OSI)

The multi-parameter REMOTS[®] Organism-Sediment Index (OSI) has been constructed to characterize habitat quality. Habitat quality is defined relative to two end-member standards. The lowest value is given to those bottoms which have low or no dissolved oxygen in the overlying bottom water, no apparent macrofaunal life, and methane gas present in the sediment (see Rhoads and Germano 1982, 1986, for REMOTS[®] criteria for these conditions). The OSI for such a condition is -10. At the other end of the scale, an aerobic bottom with a deeply depressed RPD, evidence of a mature macrofaunal assemblage, and no apparent methane gas bubbles at depth will have an OSI value of +11.

The OSI is a sum of the subset indices shown in Table 1-1. The OSI is calculated automatically by SAIC software after completion of all measurements from each REMOTS[®] photographic negative. The index has proven to be an excellent parameter for mapping disturbance gradients in an area and documenting ecosystem recovery after disturbance (Germano and Rhoads 1984, Revelas et al. 1987, Valente et al. 1992).

The OSI may be subject to seasonal changes because the mean apparent RPD depths vary as a result of temperature-controlled changes of bioturbation rates and sediment oxygen demand. Furthermore, the successional status of a station may change over the course of a season related to recruitment and mortality patterns or the disturbance history of the bottom. The sub-annual change in successional status is generally limited to Stage I (polychaete-dominated) and Stage II (amphipod-dominated) seres. Stage III seres tend to be maintained over periods of several years unless they are eliminated by increasing organic loading, extended periods of hypoxia, or burial by thick layers of dredged material. The recovery of Stage III seres following abatement of such events may take several years (Rhoads and Germano 1982). Stations that have low or moderate OSI values (< +6) are indicative of recently disturbed areas and tend to have greater temporal and spatial variation in benthic habitat quality than stations with higher OSI values (> +6).

Table 1-1

Calculation of REMOTS[®] Organism Sediment Index Value

A. CHOOSE ONE VALUE:	
<u>Mean RPD Depth</u>	<u>Index Value</u>
0.00 cm	0
> 0 - 0.75 cm	1
0.75 - 1.50 cm	2
1.51 - 2.25 cm	3
2.26 - 3.00 cm	4
3.01 - 3.75 cm	5
> 3.75 cm	6
B. CHOOSE ONE VALUE:	
<u>Successional Stage</u>	<u>Index Value</u>
Azoic	-4
Stage I	1
Stage I ® II	2
Stage II	3
Stage II ® III	4
Stage III	5
Stage I on III	5
Stage II on III	5
C. CHOOSE ONE OR BOTH IF APPROPRIATE:	
<u>Chemical Parameters</u>	<u>Index Value</u>
Methane Present	-2
No/Low Dissolved Oxygen**	-4
REMOTS[®] ORGANISM-SEDIMENT INDEX =	Total of above subset indices (A+B+C)
RANGE: -10 - +11	

** Note: This is not based on a Winkler or polarigraphic electrode measurement. It is based on the imaged evidence of reduced, low reflectance (i.e., high oxygen demand) sediment at the sediment-water interface.

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APPENDIX B

REMOTS[®] Image Analysis Results for Sites 69a and 69b, November

REMOTS® Image analysis Results for Site 69B

STAT	REPL	DATE	TIME	AYST	LAT	LONG	HAB	SS	GSMN	GSMX	GSM	PNMN	PNMX	PNRNG	PENMEAN
A2	A	11/19/99	11:36	HLS	41 14.324N	071 23.008W	UN.SS	ST_I_ON_III	3	>4	4 to 3	8.00	8.79	0.79	8.39
A2	C	11/19/99	11:38	HLS	41 14.324N	071 23.008W	HR	INDET	-1	>4	<-1	0.13	0.13	0.00	0.13
A3	C	11/19/99	11:46	HLS	41 14.087N	071 23.056W	UN.SS	ST_I_ON_III	3	>4	4 to 3	9.79	10.53	0.74	10.16
A5	C	11/19/99	12:42	HLS	41 13.615N	071 23.154W	UN.SS	ST_I_ON_III	2	>4	4 to 3	6.26	7.79	1.53	7.03
A10	B	11/19/99	13:08	HLS	41 13.957N	071 22.699W	UN.SS	ST_I	2	>4	4 to 3	7.84	8.89	1.05	8.37
A11	C	11/19/99	12:55	HLS	41 13.720N	071 22.748W	UN.SS	ST_I_TO_II	2	>4	4 to 3	9.58	10.47	0.89	10.03
A19	B	11/19/99	10:58	HLS	41 14.244N	071 24.152W	SA.F	ST_I	2	>4	4 to 3	5.74	6.84	1.11	6.29
A20	A	11/19/99	10:49	HLS	41 14.008N	071 24.206W	SA.F	ST_I	2	>4	4 to 3	3.26	4.16	0.89	3.71
A21	A	11/19/99	9:14	HLS	41 13.771N	071 24.254W	UN.SS	ST_I_TO_II	3	>4	4 to 3	4.11	5.00	0.90	4.55
A22	B	11/19/99	9:26	HLS	41 14.060N	071 24.007W	UN.SS	ST_I	2	>4	4 to 3	6.26	7.53	1.26	6.89
A23	B	11/19/99	11:08	HLS	41 14.350N	071 23.753W	UN.SS	ST_I_ON_III	3	>4	4 to 3	6.21	7.00	0.79	6.61
A24	B	11/19/99	9:32	HLS	41 14.113N	071 23.807W	UN.SS	ST_I	2	4	4 to 3	6.79	8.26	1.47	7.53
A25	B	11/19/99	9:06	HLS	41 13.876N	071 23.855W	UN.SS	ST_I_ON_III	2	>4	4 to 3	7.63	8.53	0.89	8.08
A26	B	11/19/99	12:22	HLS	41 13.640N	071 23.903W	UN.SS	ST_I	2	>4	4 to 3	6.37	7.42	1.05	6.89
A27	B	11/19/99	11:24	HLS	41 14.402N	071 23.554W	SA.F	ST_I	2	>4	4 to 3	3.42	5.05	1.63	4.24
A27	C	11/19/99	11:25	HLS	41 14.402N	071 23.554W	UN.SS	ST_I	2	>4	4 to 3	5.32	5.74	0.42	5.53
A28	C	11/19/99	10:38	HLS	41 14.166N	071 23.608W	UN.SS	ST_I_TO_II	2	>4	4 to 3	5.11	6.00	0.89	5.55
A29	B	11/19/99	8:57	HLS	41 13.929N	071 23.656W	UN.SS	ST_I	2	>4	4 to 3	4.47	5.47	1.00	4.97
A30	B	11/19/99	12:15	HLS	41 13.693N	071 23.704W	UN.SS	ST_I_ON_III	2	>4	4 to 3	4.26	5.05	0.79	4.66
A31	A	11/19/99	11:29	HLS	41 14.455N	071 23.354W	UN.SS	ST_I_TO_II	3	>4	>4	4.58	5.89	1.32	5.24
A31	B	11/19/99	11:30	HLS	41 14.455N	071 23.354W	SA.F	ST_I	2	>4	4 to 3	2.42	4.00	1.58	3.21
A32	A	11/19/99	8:44	HLS	41 14.219N	072 23.408W	UN.SS	ST_I	2	>4	4 to 3	6.79	8.05	1.26	7.42
A32	C	11/19/99	8:46	HLS	41 14.219N	072 23.408W	UN.SS	ST_I	2	>4	4 to 3	10.42	10.79	0.37	10.61
A33	A	11/19/99	11:59	HLS	41 13.982N	071 23.456W	UN.SS	ST_I	2	>4	4 to 3	6.32	6.84	0.53	6.58
A33	B	11/19/99	12:00	HLS	41 13.982N	071 23.456W	UN.SS	ST_I_TO_II	3	>4	4 to 3	6.26	7.05	0.79	6.66
A34	A	11/19/99	12:08	HLS	41 13.745N	071 23.504W	UN.SS	ST_I_TO_II	2	>4	4 to 3	4.11	4.68	0.58	4.39
A35	A	11/19/99	12:32	HLS	14 13.509N	071 23.552W	UN.SS	ST_I_TO_II	3	>4	4 to 3	6.32	6.95	0.63	6.63

REMOTS® Image analysis Results for Site 69B

RPDMN	RPDMX	RPDMEAN	OSI	SURF	CMNT						
1.58	3.16	2.29	9	PHYSICAL		tan very fine sand/gr sandy silt		st I tubes		void @Z	worm
NA	NA	NA	99	BIOGENIC	no pen	rocks and mercenera? Shells				wood frag.	
1.11	2.37	1.80	8	PHYSICAL		very fine silty sand	mod sorted	ST I tubes		sm voids	lg void/burrow @Z
1.75	3.60	3.10	10	BIOGENIC		very fine silty sand				voids	burrow
1.95	4.53	3.25	6	PHYSICAL		very fine silty sand	mod sorted	ST I tubes	rippled	thin worms?	
0.53	3.15	2.55	6	BIOGENIC		very fine silty sand	mod sorted	ST I tubes		thin worms @ depth	
3.42	6.37	4.85	7	PHYSICAL		silty fine sand	poorly sorted	ST I tubes	rippled		
3.26	4.16	3.71	6	PHYSICAL		very f.sand	mod sorted	ST I tubes	rippled	RPD>pen	shrimp on surf
4.11	5.00	4.55	8	PHYSICAL		very fine sand	mod sorted	ST II?		RPD>pen	
2.32	6.68	4.43	7	PHYSICAL		very fine sand	mod sorted	ST I tubes	rippled		shell @depth
1.68	3.42	2.69	9	PHYSICAL	S/M	tan sandy silt/gr clayey silt	poorly sorted	ST I tubes		deposit feeder @Z	
3.26	6.42	4.49	7	PHYSICAL		fine sand	mod sorted	ST I tubes	rippled		
0.53	1.84	1.00	7	PHYSICAL	M/S/M	tan v.f.sand silt/gr silt/br f.sand	poorly sorted	ST I tubes	rippled	voids	
0.89	2.95	1.90	4	PHYSICAL		fine sand w/gr bk streaks	mod sorted	surf tubes?	rippled		
1.00	2.68	1.51	4	PHYSICAL		tan very fine sand/gr clayey silt	poorly sorted	surf tubes			
1.21	2.21	1.65	4	PHYSICAL	M/S	tan sandy silt/gr silt/br f.sand	poorly sorted			voids @Z	sm gr mudclast on surf
0.37	2.26	0.93	4	PHYSICAL	M/S	tan f. sandy silt/gr silt/br sand	poorly sorted	dense tube mats			
1.00	3.50	2.75	5	PHYSICAL		very fine silty sand w/gr clay @Z	mod sorted		rippled		gr wiper clast
1.00	4.21	1.77	8	PHYSICAL	S/M	tan silty sand/gr silt		sm ST I tubes	rippled	feeding void	
0.42	2.37	1.05	4	PHYSICAL	M/S	tan silt/gr clayey silt/br sandy silt	poorly sorted		rippled		bk streaks
1.47	3.26	2.07	4	PHYSICAL		tan very fine sand/v.f. gr sand	mod sorted	surf tubes	rippled		
0.47	2.53	1.64	4	PHYSICAL		fine sand	mod sorted	ST I tubes?	rippled		seastar
1.16	3.45	2.85	5	PHYSICAL	M/S	tan f.silty sand/gr ss/br f-m sand	poorly sorted	ST I tubes			
0.58	2.21	1.08	3	PHYSICAL	M/S	tan silt/gr silt/br sand	poorly sorted	ST I tubes			
3.00	5.74	4.26	8	PHYSICAL		very fine silty sand	mod sorted	ST I tubes		thin worm@Z	
0.68	2.37	1.40	4	PHYSICAL		very fine silty sand	mod sorted	ST I tubes		poss. ST II	
0.74	1.95	1.24	4	INDET		tan f.silty sand/gr silty sand/br sand	poorly sorted	dense ST I&II tubemat			seastar in distance

REMOTS® Image Analysis Results for Site 69A

STAT	REPL	DATE	TIME	AYST	LAT	LONG	HAB	SS	GSMN	GSMX	GSMM	PNMN	PNMX	PNRNG	PENMEAN
B2	A	11/19/99	15:09	HLS	41 14.954N	071 19.821W	UN.SS	ST_I_TO_II	2	>4	4 to 3	6.37	6.84	0.47	6.61
B6	B	11/19/99	15:01	HLS	41 14.435N	071 19.821W	UN.SS	ST_I	2	>4	4 to 3	6.21	7.11	0.89	6.66
B11	C	11/19/99	14:54	HLS	41 14.564N	071 19.463W	UN.SS	ST_I_ON_III	2	>4	4 to 3	7.58	8.16	0.58	7.87
B15	C	11/19/99	14:36	HLS	41 14.824N	071 19.105W	UN.SS	ST_I_ON_III	2	>4	4 to 3	3.05	3.89	0.84	3.47
B18	A	11/19/99	14:43	HLS	41 14.435N	071 19.105W	UN.SS	ST_I	2	>4	4 to 3	2.79	4.16	1.37	3.47
B19	B	11/19/99	14:00	HLS	41 15.213N	071 20.184W	UN.SS	ST_I	2	4	4 to 3	4.21	4.53	0.32	4.37
B20	C	11/19/99	13:56	HLS	41 15.083N	071 20.184W	UN.SS	ST_I_ON_III	2	>4	4 to 3	4.89	5.42	0.53	5.16
B21	C	11/19/99	13:48	HLS	41 14.954N	071 20.184W	SA.F	ST_I	2	4	4 to 3	3.00	4.16	1.16	3.58
B22	A	11/19/99	13:39	HLS	41 14.824N	071 20.184W	UN.SS	ST_I_TO_II	2	>4	4 to 3	3.53	4.79	1.26	4.16
B23	B	11/19/99	13:35	HLS	41 14.694N	071 20.184W	UN.SS	ST_I	2	>4	4 to 3	4.37	5.47	1.11	4.92
B24	B	11/19/99	13:31	HLS	41 14.564N	071 20.184W	SA.F	ST_I	3	4	4 to 3	3.32	4.42	1.11	3.87
B25	C	11/19/99	13:26	HLS	41 14.435N	071 20.184W	SA.F	ST_I	2	>4	4 to 3	2.47	3.68	1.21	3.08
B26	B	11/19/99	14:07	HLS	41 15.213N	071 19.832W	SA.F	ST_I	2	>4	4 to 3	2.26	3.37	1.11	2.82
B27	A	11/19/99	14:13	HLS	41 15.213N	071 19.481W	UN.SS	ST_I_ON_III	3	>4	4 to 3	3.89	4.95	1.05	4.42
B28	C	11/19/99	14:21	HLS	41 15.213N	071 19.130W	UN.SS	ST_I_TO_II	3	>4	4 to 3	3.79	4.32	0.53	4.05

REMOTS® Image Analysis Results for Site 69A

STAT	REPL	RPDMN	RPDMX	RPDMEAN	OSI	SURF	CMNT					
B2	A	1.16	3.32	1.94	5	PHYSICAL	very fine sand w/lt gr	mod sorted	dense ST I tubemat			
B6	B	1.32	2.63	2.03	4	PHYSICAL	fine sand	mod sorted	ST I tubes			rippled
B11	C	2.00	4.63	3.12	10	BIOGENIC	very fine silty sand		lg void and shell @ depth			
B15	C	2.11	3.79	3.07	10	PHYSICAL	very fine silty sand		sm void	a few bk pebbles on surf		
B18	A	0.74	2.89	1.49	3	PHYSICAL	tan sandy silt/gr silt		sm ST I tubes	red.mudclasts		
B19	B	2.26	4.16	3.43	6	BIOGENIC	very fine silty sand	mod sorted	seastar	shell frag.		
B20	C	1.37	4.53	2.74	9	PHYSICAL	very fine sand	mod sorted	sm feeding voids	a few shell frag.		
B21	C	2.95	4.21	3.36	6	PHYSICAL	very fine sand	well sorted	sm ST I tubes		RPD>pen	rippled
B22	A	3.42	4.89	4.06	8	PHYSICAL	fine sand		ST I tubes	Poss. AM?	RPD>pen	
B23	B	4.37	5.47	3.87	7	PHYSICAL	very fine sand	mod sorted			RPD>pen	
B24	B	3.32	4.42	3.87	7	PHYSICAL	fine beach sand	mod sorted	2 sand dollars (1 buried)		RPD>pen	
B25	C	2.47	3.68	3.08	6	PHYSICAL	dk br very f. silty sand	mod sorted	shell frag.		RPD>pen	
B26	B	2.37	3.53	2.86	5	PHYSICAL	very fine silty sand	mod sorted	few sm shell frags		RPD>pen	rippled
B27	A	2.85	4.95	3.11	10	PHYSICAL	very f. silty sand	mod sorted	ST I tubes/ST II?	lg&sm voids		
B28	C	0.79	2.95	1.70	5	PHYSICAL	very fine silty sand	mod sorted	clam shell at surf			

APPENDIX I-4

**RHODE ISLAND SOUND FISH DATA ANALYSIS FOR THE
PROVIDENCE RIVER MAINTENANCE DREDGING ENVIRONMENTAL IMPACT
STATEMENT**

Submitted to

**Department of the Army
U.S. Army Corps of Engineers
North Atlantic Division
New England District**

**Contract No. DACW33-96-D-0005
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Methods

Data from the National Marine Fisheries Service (NMFS) annual spring/fall bottom trawl surveys from an area encompassing the three Rhode Island Sound potential disposal sites (Site 18, Brenton A; Site 69a, Jamestown Bridge Reef; and Site 69b, Separation Zone) were used to evaluate the fisheries resource at each site. Trawls in relatively close proximity to each potential disposal site were selected for inclusion in the analysis. Some trawls were used to represent two sites because they were about equidistant between them. Specific trawls are listed in Table 1; their locations are shown in Figure 1. The sampling design, survey, and assessment methods are provided in Azarovitz (1981).

The trawl data consisted of the number of individuals of each species caught for a series of trawls taken near each of three potential dredged materials disposal sites. The 16 individual trawl events ranged in time from August 1965 to October 1998. The number of trawl events was divided between the spring (January – June; $n = 8$) and fall (July – December; $n = 8$) seasons. There were at least two trawl events in the spring or fall near each potential disposal site across all years.

It should be noted that, without direct knowledge as to the effort applied for each trawl event (*e.g.*, length of tow, mesh size), the analyses assumed equal effort for each event. Use of this assumption increases the variability of the data and diminishes the ability to use the data to differentiate among the fisheries resource at the three sites. Similarly, use of some trawls to represent two sites also reduces the ability to use the trawl data to differentiate among the sites.

Statistical Methods

The statistical analysis of trawl data was conducted in three stages to estimate a likelihood of occurrence of each species, ranging from very low to high, during either the spring or fall at each potential disposal site. For the first stage of the analysis, a *regional likelihood of occurrence* was estimated using the presence/absence of each species in trawl data for each season (*i.e.*, spring or fall) and year round (*i.e.*, spring and fall combined). The second stage of analysis was estimation of a *local likelihood of occurrence* using the presence/absence of each species using only the trawl data associated with a given disposal site. For the third stage of analysis, the regional and local estimates of the likelihood of occurrence were combined to produce a *final estimate of likelihood of occurrence*. This final estimate of likelihood of occurrence required a subjective weighing of species-specific information. The two questions asked were (1) was the species population increasing or declining, determined using Kendall's test of concordance ($\alpha = 0.1$), and (2) was the species caught only seasonally (*i.e.*, spring or fall).

The first stage was to analyze the data to estimate a *regional likelihood of occurrence*. The presence of a species at all sites and in at least 70% of the trawl events implied that the species is common regionally. The value of 70% was a subjective criterion applied to indicate the frequent or common presence of a species. The number of a given species caught during a trawl event was not considered at this point, but it was used during the third stage of analysis to suggest a possible increase or decline in population using all of the trawl data. The presence of a species caught at all sites within at least 70% of spring or fall trawl events implied that the species was common regionally during a specific season. Thus, the estimate of the likelihood of occurrence was high for at least some part of the year. The likelihood of occurrence for species that did not meet these criteria were designated as something less than high (*e.g.*, an intermediate or very low classification level) and was not evaluated further in this stage.

The second stage of analysis was to evaluate only the trawl data associated with the potential disposal site to estimate a *local likelihood of occurrence*. The local likelihood of occurrence for a species was designated as high if it was caught during all trawl events for a given disposal site. The local likelihood

of occurrence for a species was designated as very low if it was not caught during any of the trawl events for a given disposal site. Intermediate categories, or classification levels, were assigned to the local likelihood of occurrence for each species based on three weighing schemes. An equally weighted count (*i.e.*, all trawl events are considered of equal weight) of the number of times the species was caught out of the total number of trawl events was calculated for the *equal-weight estimate*.

For example, presence in trawls at frequencies of 4 out of 5, 3 out of 5, 2 out of 5, and 1 out of 5 were designated as moderately high, moderate, moderately low, and low, respectively. Two additional estimates of the intermediate classification levels for local likelihood of occurrence were made based on the sequence and number of trawl events in which a species was caught. One estimate, defined as *season weighted*, was based on whether the species was caught during either the last two spring or fall trawl events, as well as the number of events in which it was caught. Another estimate, defined as *time weighted*, was based on whether the species was caught during the last three trawl events and the number of events in which it was caught.

The three estimates of the local likelihood of occurrence provided an unqualified counting of events (equally weighted estimate) and biological constraints (seasonal and time weighted estimates). For example, if a species were caught in any of three out of five trawl events designated as S₇₃, S₇₉, F₈₀, F₉₀, and S₉₅ (for the season and year of the event), the equally weighted estimate of the likelihood of occurrence would be 3 out of 5, which was categorized as moderate. If the species was caught in both of the fall trawls (*e.g.*, F₈₀ and F₉₀) and one of the spring trawls, the local likelihood of occurrence would be estimated as seasonal moderate. If the species was caught in the three most recent trawls (*e.g.*, F₈₀, F₉₀, and S₉₅) the local likelihood of occurrence would be estimated as both seasonal and time weighted moderate.

The third stage of analysis was to combine the regional and local estimates of the likelihood of occurrence using species-specific information. Decisions were made in a manner to minimize subjectivity. The criteria used for the *final determination of the likelihood of occurrence* were the following. If a species was seasonal and not decreasing, the local estimate of occurrence was increased by one classification level (*e.g.*, moderate categorization was increased to moderately high, or low was increased to moderately low). If a species appeared to be increasing or decreasing regionally in abundance (based on number of individuals caught in trawls), the local estimate of occurrence was increased or decreased by one classification level, respectively. For all other cases, the local time- or seasonal-weighted estimates of occurrence were used as the final estimate of occurrence. If only a local equally weighted estimate of occurrence was available, it was decreased by one classification level to determine the final estimate of occurrence. For example, a species initially categorized as moderate (because it had been caught in 3 of 7 trawls) would be categorized as moderately low because it was not present seasonally or consistently in recent trawls.

Results

Species caught at all sites during at least 70% of the trawl events were assumed to represent species that were common to sites throughout the year. These species were the little skate, longhorn sculpin, sea raven, silver hake, windowpane, winter flounder, and the American lobster (Table 2). None of these species was found to be consistently declining through time using Kendall's test of concordance ($\alpha = 0.1$). Species that were common to all sites only during the spring were the alewife, Atlantic cod, Atlantic herring, and the ocean pout. None of these species was found to be consistently increasing or declining through time ($\alpha = 0.1$). Species that were common to all sites only during the fall were the butterfish, fourspot flounder, northern searobin, scup, and the spiny dogfish. None of these species was found to be consistently declining through time ($\alpha = 0.1$). However, the abundance of three species in

fall trawls, the fourspot flounder, little skate, and American lobster, was found to have consistently increased through time (using Kendall's test of concordance, $\alpha = 0.1$).

The local analysis for each disposal site was conducted using a time-weighted estimate, a seasonally weighted estimate, and an equally weighted estimate of the likelihood of occurrence. For Site 18, alewife and winter flounder were the only two species caught during each trawl event ($n = 7$). For Site 69a, little skate, sea raven, winter flounder, and the American lobster were caught during each trawl event ($n = 7$). For Site 69b, little skate, sea raven, silver hake, windowpane, winter flounder, and the American lobster were caught during each trawl event ($n = 5$). The likelihood of occurrence for these species at the respective disposal sites was categorized as high. The local analysis for each site is depicted in Tables 3 through 5.

The final analysis, which combines findings from the regional and local analyses, is depicted in Table 6. The effect of combining analyses is that the local estimated likelihood of occurrence might increase (or decrease) of by one classification level (*e.g.* moderately high, moderate, moderately low, and low) because of an increasing (or decreasing) population trend, or because of a seasonal trend. Review of Table 6 reveals that a different assemblage of species is associated with each potential disposal site. Species in the "high" category are highly likely to be present at a given site. Conversely, species in the "low" or "very low" category were rarely or never found at a given site, and they are highly unlikely to be impacted by activities at the site. The combined analysis identified three species, winter flounder, little skate, and American lobster, showed a high likelihood of occurrence at all three potential disposal sites.

Reference

Azarovitz, T.R. 1981. A brief historical review of the Woods Hole Laboratory trawl survey time series. Canadian Special Publication of Fisheries and Aquatic Sciences 58:62-66.

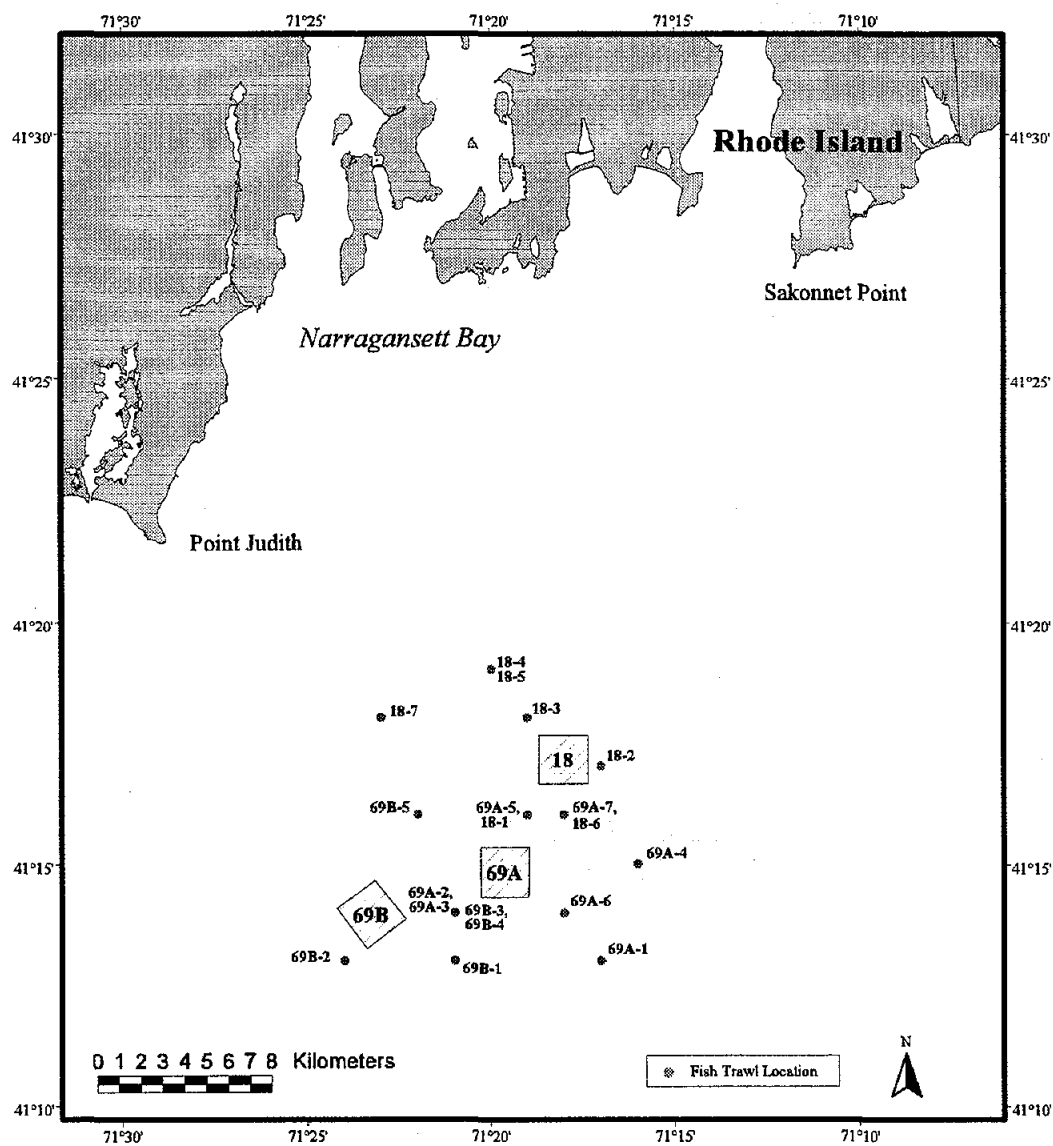


Figure 1. Location of National Marine Fisheries Service trawls used for evaluation of fishery resources at Rhode Island Sound potential disposal sites.

Table 1. Locations of National Marine Fisheries Service trawls used in analyses of fishery resources at Rhode Island Sound potential disposal sites.

Trawl Number	Latitude (N)	Longitude (W)	Season/Year	Comment
Site 18 Brenton Reef				
1	41° 16'	71° 19'	S93	Same trawl as 69a-5
2	41° 17'	71° 17'	F70	
3	41° 18'	71° 19'	F65	
4	41° 19'	71° 20'	S80	Same location as 18-5, different date
5	41° 19'	71° 20'	S78	Same location as 18-4, different date
6	41° 16'	71° 18'	F98	
7	41° 18'	71° 23'	F97	
Site 69a Jamestown Bridge Reef				
1	41° 13'	71° 17'	S85	
2	41° 14'	71° 21'	F84	Same location as 69a-3, different date; same trawl as 69b-3
3	41° 14'	71° 21'	F97	Same location as 69a-2, different date; same trawl as 69b-4
4	41° 15'	71° 16'	F96	
5	41° 16'	71° 19'	S93	Same trawl as 18-1
6	41° 14'	71° 18'	S98	
7	41° 16'	71° 18'	S98	
Site 69b Separation Zone				
1	41° 13'	71° 21'	S96	
2	41° 13'	71° 24'	F92	
3	41° 14'	71° 21'	F84	Same location as 69b-4, different date; same trawl as 69a-2
4	41° 14'	71° 21'	F97	Same location as 69b-3, different date; same trawl as 69a-3
5	41° 16'	71° 22'	S73	

Table 2. Species common to all trawl sites at least during part of the year.

All Year	Spring	Fall
Little skate	Alewife	Butterfish
Longhorn sculpin	Atlantic cod	Fourspot flounder
Sea raven	Atlantic herring	Northern searobin
Silver hake	Ocean pout	Scup
Windowpane		Spiny dogfish
Winter flounder		
American lobster		

Table 3. The local analysis of fishery resources at potential disposal Site 18.

		Time Wt	Season Wt	Equal Wt	Time Wt	Season Wt	Equal Wt	Time Wt	Season Wt	Equal Wt	Time Wt	Season Wt	Equal Wt	Time Wt	Season Wt	Equal Wt	Time Wt	Season Wt	Equal Wt	
	1	0.86	0.86	0.86	0.71	0.71	0.71	0.57	0.57	0.57	0.43	0.43	0.43	0.29	0.29	0.29	0.14	0.14	0.14	
Occurrence								4 of 7	4 of 7	4 of 7				2 of 7	2 of 7	2 of 7	1 of 7	1 of 7	1 of 7	0 of 7
Common Name																				
Alewife		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
American shad	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0
Atlantic cod	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
Atlantic herring	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
Atlantic mackerel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Atlantic silverside	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
Barndoor skate	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Bay anchovy	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Black sea bass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0
Blueback herring	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Bluefish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Butterfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Conger eel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0
Cunner	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fourspot flounder	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Goosefish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gulf Stream flounder	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0
Little skate	0	0	0	0				0	0	0	0	0	0	0	0	0	0	0	0	0
Longhorn sculpin	0	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0
Lookdown	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Northern kingfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Northern sand lance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Northern searobin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0
Ocean pout	0	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0
Pollack	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Radiated shanny	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0
Rainbow smelt	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Red hake	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
Rough scad	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Scup	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Sea raven	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0
Silver hake	0	0	0	0				0	0	0	0	0	0	0	0	0	0	0	0	0

Table 3. The local analysis of fishery resources at potential disposal Site 18. (continued).

		Time Wt	Season Wt	Equal Wt	Time Wt	Season Wt	Equal Wt	Time Wt	Season Wt	Equal Wt	Time Wt	Season Wt	Equal Wt	Time Wt	Season Wt	Equal Wt	Time Wt	Season Wt	Equal Wt	
Slender sole	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Smallmouth flounder	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0
Smooth dogfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Spiny dogfish	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0
Spotted hake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Striped searobin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0
Summer flounder	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0
White hake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Windowpane	0	0	0	0	0	0	0	0	0	0				0	0	0	0	0	0	0
Winter flounder		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Winter skate	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0
Yellowtail flounder	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0
American lobster	0				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Longfin squid	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0
								1	4	5				3	3	5	9	10	14	9
		High			Moderately High			Moderate					Moderately Low			Low			Very Low	

Table 4. The local analysis of potential disposal Site 69a.

		Time Wt	Season Wt	Equal Wt	Time Wt	Season Wt	Equal Wt	Time Wt	Season Wt	Equal Wt	Time Wt	Season Wt	Equal Wt	Time Wt	Season Wt	Equal Wt	Time Wt	Season Wt	Equal Wt	
	1	0.86	0.86	0.86	0.71	0.71	0.71	0.57	0.57	0.57	0.43	0.43	0.43	0.29	0.29	0.29	0.14	0.14	0.14	
Occurrence								4 of 7	4 of 7	4 of 7				2 of 7	2 of 7	2 of 7	1 of 7	1 of 7	1 of 7	0 of 7
Common Name																				
Alewife	0	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0	0	0
American shad	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Atlantic cod	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
Atlantic herring	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
Atlantic mackerel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Atlantic silverside	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Barndoor skate	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Bay anchovy	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Black sea bass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Blueback herring	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Bluefish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Butterfish	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0	0
Conger eel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Cunner	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0
Fourspot flounder	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
Goosefish	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0
Gulf Stream flounder	0	0	0	0	0	0	0	0	0	0				0	0	0	0	0	0	0
Little skate		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Longhorn sculpin	0				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lookdown	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Northern kingfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Northern sand lance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0
Northern searobin	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0	0
Ocean pout	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
Pollack	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Radiated shanny	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Rainbow smelt	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Red hake	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
Rough scad	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Scup	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0	0
Sea raven		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Silver hake	0				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 4. The local analysis of potential disposal Site 69a (continued).

		Time Wt	Season Wt	Equal Wt	Time Wt	Season Wt	Equal Wt	Time Wt	Season Wt	Equal Wt	Time Wt	Season Wt	Equal Wt	Time Wt	Season Wt	Equal Wt	Time Wt	Season Wt	Equal Wt	
Slender sole	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Smallmouth flounder	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0
Smooth dogfish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Spiny dogfish	0	0	0	0	0	0	0	0	0	0				0	0	0	0	0	0	0
Spotted hake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
Striped searobin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Summer flounder	0	0	0	0	0	0	0	0	0	0				0	0	0	0	0	0	0
White hake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Windowpane	0				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Winter flounder		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Winter skate	0	0	0	0				0	0	0	0	0	0	0	0	0	0	0	0	0
Yellowtail flounder	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0
American lobster		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Longfin squid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
								0	5	5				3	3	6	1	1	10	9
		High			Moderately High			Moderate					Moderately Low				Low		Very Low	

Table 5. The local analysis of potential disposal Site 69b.

		Time Wt	Season Wt	Equal Wt	Time Wt	Season Wt	Equal Wt	Time Wt	Season Wt	Equal Wt	Time Wt	Season Wt	Equal Wt	
	1	0.80	0.80	0.80	0.60	0.60	0.60	0.40	0.40	0.40	0.20	0.20	0.20	
Occurrence								2 of 5	2 of 5	2 of 5	1 of 5	1 of 5	1 of 5	0 of 5
Common Name														
Alewife	0	0	0	0	0	0	0	0	1	1	0	0	0	0
American shad	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Atlantic cod	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Atlantic herring	0	0	0	0	0	0	0	0	1	1	0	0	0	0
Atlantic mackerel	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Atlantic silverside	0	0	0	0	0	0	0	0	0	0	1	1	1	0
Barndoor skate	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Bay anchovy	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Black sea bass	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Blueback herring	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Bluefish	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Butterfish	0	0	0	0	0			0	0	0	0	0	0	0
Conger eel	0	0	0	0	0	0	0	0	0	0	1	1	1	0
Cunner	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Fourspot flounder	0	0	0	0	0			0	0	0	0	0	0	0
Goosefish	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Gulf Stream flounder	0	0	0	0	0	0	0	0	1	1	0	0	0	0
Little skate	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Longhorn sculpin	0				0	0	0	0	0	0	0	0	0	0
Lookdown	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Northern kingfish	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Northern sand lance	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Northern searobin	0	0	0	0	0			0	0	0	0	0	0	0
Ocean pout	0	0	0	0	0	0	0	0	1	1	0	0	0	0
Pollack	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Radiated shanny	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Rainbow smelt	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Red hake	0	0	0	0	0			0	0	0	0	0	0	0
Rough scad	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Scup	0	0	0	0	0			0	0	0	0	0	0	0
Sea raven	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Silver hake	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Slender sole	0	0	0	0	0	0	0	0	1	1	0	0	0	0
Smallmouth flounder	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Table 5. The local analysis of potential disposal Site 69b (continued).

		Time Wt	Season Wt	Equal Wt	Time Wt	Season Wt	Equal Wt	Time Wt	Season Wt	Equal Wt	Time Wt	Season Wt	Equal Wt	
Smooth dogfish	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Spiny dogfish	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Spotted hake	0	0	0	0	0	0	0	0	1	1	0	0	0	0
Striped searobin	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Summer flounder	0	0	0	0	0	0	0	0	0	1	0	0	0	0
White hake	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Windowpane		0	0	0	0	0	0	0	0	0	0	0	0	0
Winter flounder		0	0	0	0	0	0	0	0	0	0	0	0	0
Winter skate	0	0	0	0	0	0		0	0	0	0	0	0	0
Yellowtail flounder	0	0	0	0	0	0	0	0	0	0	0	0	0	1
American lobster		0	0	0	0	0	0	0	0	0	0	0	0	0
Longfin squid	0	0	0	0	0			0	0	0	0	0	0	0
								0	6	8	2	2	7	17
	High	Moderately High			Moderate			Moderately Low			Low			Very Low

Table 6. The final estimate of the likelihood of occurrence for each species at each potential disposal site.

Site 18	Site 69a	Site 69b	Category
Alewife	Alewife	Little skate	High
Ocean pout	Little skate	Sea raven	
Winter flounder	Longhorn sculpin	Silver hake	
Little skate	Sea raven	Windowpane	
American lobster	Silver hake	Winter flounder	
	Windowpane	American lobster	
	Winter flounder		
	American lobster		
Atlantic cod	Atlantic cod	Butterfish	Moderately High
Atlantic herring	Atlantic herring	Fourspot flounder	
Longhorn sculpin	Fourspot flounder	Longhorn sculpin	
Silver hake	Ocean pout	Northern searobin	
	Winter skate	Scup	
Butterfish	Butterfish	Alewife	Moderate
Cunner	Gulf Stream flounder	Atlantic herring	
Fourspot flounder	Northern searobin	Ocean pout	
Red hake	Red hake	Red hake	
Sea raven	Scup	Longfin squid	
Spiny dogfish	Spiny dogfish		
Windowpane	Summer flounder		
Goosefish	Cunner	Gulf Stream flounder	Moderately Low
Gulf Stream flounder	Goosefish	Slender sole	
Northern searobin	Smallmouth flounder	Spiny dogfish	
Slender sole	Spotted hake	Spotted hake	
Winter skate	Yellowtail flounder	Winter skate	
Longfin squid			
American shad	Atlantic silverside	Atlantic silverside	Low
Atlantic silverside	Northern sand lance	Conger eel	
Black sea bass	Longfin squid	Summer flounder	
Blueback herring			
Conger eel			
Radiated shanny			
Smallmouth flounder			
Striped searobin			
Summer flounder			
White hake			
Yellowtail flounder			
Atlantic mackerel	American shad	American shad	Very Low
Barndoor skate	Atlantic mackerel	Atlantic cod	
Bay anchovy	Barndoor skate	Atlantic mackerel	
Bluefish	Bay anchovy	Barndoor skate	
Lookdown	Black sea bass	Bay anchovy	
Northern kingfish	Blueback herring	Black sea bass	
Northern sand lance	Bluefish	Blueback herring	
Pollack	Conger eel	Bluefish	
Rainbow smelt	Lookdown	Cunner	
Rough scad	Northern Kingfish	Goosefish	
Scup	Pollack	Lookdown	
Smooth dogfish	Radiated shanny	Northern kingfish	
Spotted hake	Rainbow smelt	Northern sand lance	
	Rough scad	Pollack	
	Slender sole	Radiated shanny	
	Smooth dogfish	Rainbow smelt	
	Striped searobin	Rough scad	
	White hake	Smallmouth flounder	
		Smooth dogfish	
		Striped searobin	
		White hake	
		Yellowtail flounder	